CRHIAM

CENTRO DE RECURSOS HÍDRICOS PARA LA AGRICULTURA Y LA MINERÍA

ANID/FONDAP/15130015

Annual Report 2022

Agriculture Sustainability Water Biodiversity Formation Mining Ecosystem Excellence in Research Water Scarcity Communities

Universidad de Concepción

UNIVERSIDAD DE LA FRONTERA

Universidad del Desarrollo
Universidad de Excelencia

Agencia Nacional de Investigación y Desarrollo
Ministerio de Ciencia, Tecnología, Conocimiento e Innovación
Gobierno de Chile

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1 Message from the directors

During 2022, the Water Research Center for Agriculture and Mining continued its work thanks to the support of the National Research and Development Agency's (ANID) Fund for Research Centers in Priority Areas (FONDAP). The Center has continued working to generate research and advanced technological knowledge on water resources for agriculture, mining and communities, in order to contribute to the fulfillment of the sustainable development objectives, understanding the multidimensional nature of the water crisis and mega drought affecting the country.

Chile is one of the countries hardest hit by climate change and drought. Understanding this scenario and the urgency of seeking effective solutions in water matters for such priority areas for the country, such as agriculture and mining, in 2022 CRHIAM worked hard to generate products and initiatives that would contribute to public policies with excellence scientific evidence.

In this sense, the preparation of "Policy Briefs" stands out, which are documents to generate dissemination of scientific evidence that contributes to public policies, through the delivery of relevant and timely information. These documents address problems of the national contingency in environmental matters and water resources, and present recommendations for the authorities, with the aim of supporting decision-making based on scientific evidence. In addition, work continued on the writing of the "CRHIAM Communication Series", which seeks to promote issues from an interdisciplinary perspective, with the aim of disseminating them to public and private decision makers and the general community.

This year it was published the CRHIAM Communication Series Special Edition "Environmental quality of drinking water sources of sanitation service companies in Chile. Period 2014-2020". The main objective of this report is to publicize the environmental quality of water catchment sources focused on the protection of aquatic ecosystems. We worked with data requested by the Transparency Law through the tool requesting public information from the Superintendency of Sanitary Services (SISS). This document was prepared by members of the Center (principal researchers and collaborators), with the collaboration of the Aquatic Ecosystems Department of the Natural Resources and Biodiversity Division of the Ministry of the Environment, and the technical review of the study was carried out by the Technical Unit of the Inspection Division of the Superintendency of Sanitary Services (SISS).

It should be noted that CRHIAM continued to work together with the public and private sectors, and making scientific work visible through appearances in the press, talks, international seminars and participating in scientific fairs. Among these, the Water Forum stands out, the participation in the "Exploradores" program broadcast on the channel 24 Horas, the fortnightly publication of the podcast "El Agua tiene su Ciencia" and the monthly broadcast of the CRHIAM Talk Cycle.

Regarding the training of advanced human capital in water resources, the Center continued teaching in 100% e-learning the "Diploma in Water Resources for Sustainable Development", a program from which more than 90 professionals from different cities of the country have already graduated during the 2019-2022 period. In addition, there were 14 postdoctoral researchers actively working at CRHIAM; while 12 doctoral students, 13 master's students and 51 professionals from different undergraduate training graduated during 2022.

All these results make us extremely proud and motivate us to continue working for better management of the country's water resources, under the umbrella of water security. Special thanks to the National Research and Development Agency for its support and our National Advisory Council and International Scientific Committee and evaluators for their insights and support during this year of work. We also appreciate the important continued support of Universidad de Concepción, Universidad de La Frontera and Universidad del Desarrollo. And to the entire administrative team of the Center, for the work and dedication they do every day to continue positioning CRHIAM as a benchmark in water resources research for the country.

Dr. Gladys Vidal
CRHIAM Director

Dr. Pedro Toledo
CRHIAM Deputy Director

CRHIAM

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2 A description of CRHIAM

2.1 The Foundation of CRHIAM

Under a scenario of global climate change, it is essential that agriculture, mining, and communities develop sustainable practices to manage and use water resources responsibly. This means caring for water in quantity and quality, allowing it to act resiliently in the face of natural environmental changes accelerated by anthropic actions.

Given the importance of proper water resource management, in 2014 the Water Research Center for Agriculture and Mining (CRHIAM) was founded under the framework of ANID's (formerly CONICYT) fifth funding contest, called the Fund for Research Centers in Priority Areas (FONDAP) competition. The Universidad de Concepción leads CRHIAM in association with the Universidad de La Frontera and Universidad del Desarrollo. CRHIAM obtained new funding in 2019 as an interdisciplinary and collaborative research institution in the areas of agriculture and mining for the 2019-2023 period.

The solutions must range from new technologies to the reformulation of public policies that consider the ecosystem as a key part of achieving sustainability. In this sense, the work carried out by the different lines of research at CRHIAM generates a robust scientific base to support making the best decisions for correct water management.

Mission

To be a national authority on the creation of advanced scientific and technological knowledge on water resources for agriculture, mining and communities and contribute to the achievement of sustainable development goals.

Vision

To be a worldwide authority as a water resources research center for the sustainable development of agriculture, mining and communities, in consideration of the principles of water security.

Objectives

CRHIAM has four main objectives:

1. Promote world-class research on water resources to create knowledge and develop technologies to contribute to the water security of ecosystems, communities and production sectors.
2. Form undergraduate and especially graduate and postdoctoral human resources in order to create a critical mass that will support the development of abilities in the water resources field.
3. Create networks with the main domestic and international research institutions and the public and private sectors to benefit common interests regarding research, innovation and development in water resources.
4. Contribute to better water management through communication and dissemination of scientific evidence that contributes to public policies and the knowledge of society.

2.2 Our center and its associations

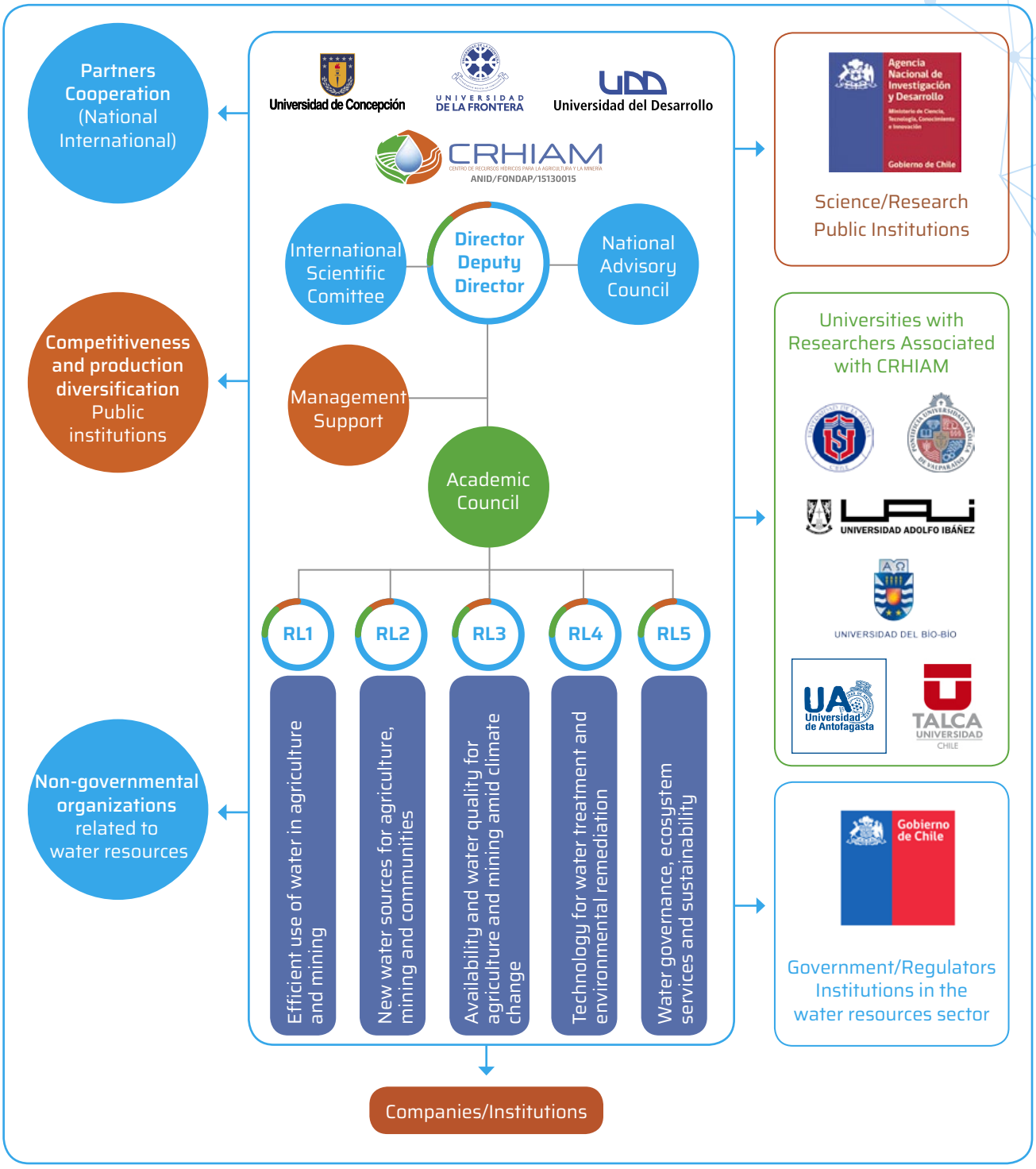

Figure 1. CRHIAM Organizational Chart. RL: Research Line.

2.3 Our administrative and logistical support team

The CRHIAM team is led by its directors and supported by administrative and logistical staff. CRHIAM's management structure is hierarchical, as shown in Figure 2.

Figure 2. CRHIAM Team Organizational Chart.

2.4 Scientific Committee

From October 24th to 27th, a new annual meeting was held with the members of the International Scientific Committee of the CRHIAM, an instance where the Center receives feedback based on the execution of the last year.

The first block of the meeting began with a presentation by the director of CRHIAM, Dr. Gladys Vidal, in which she showed the progress and work carried out by the Center in 2022. Later it was the turn of the deputy director of CRHIAM, Dr. Dr. Pedro Toledo, who presented the evaluation review of the CRHIAM 2022 report based on the evaluation to the Center for the year 2021.

Meanwhile, the second part of the meeting focused on publicizing the progress of the CRHIAM continuity project and the focus of the new lines of research. This presentation was given by the principal researchers of the Center, Dr. José Luis Arumí and Dr. Leopoldo Gutiérrez.

This is the first face-to-face meeting that brings together the main CRHIAM researchers with the International Scientific Committee, after the health emergency caused by COVID-19. On this occasion, the researchers Dr. Neil McIntyre from the University of Quensland, Dr. Jan Hopmans, professor emeritus from the University of California, and Dr. Kelly Munkittrick from the University of Calgary attended.

Figure 3. Annual meeting with our International Scientific Committee.

2.5 Advisory Council

On June 16th, the first meeting between CRHIAM principal researchers and the National Advisory Council of the Center was held virtually (Figure 4.a), a group made up of representatives of the public and private sectors whose objective is to contribute to the link with the external environment and recommend strategies for connect the work of the Center with society, government representatives and private sector organizations.

On this occasion, the meeting began with a presentation by CRHIAM Director, Dr. Gladys Vidal, who presented the progress of recent years and the challenges that the Center must face with a view to the continuity project. After that, the Executive Secretary of the National Irrigation Commission, Wilson Ureta, made a presentation on the new general guidelines of this body.

To end the meeting, the members of the Council spoke with the main researchers of CRHIAM, in order to analyze and discuss the execution and continuity of the Fondap CRHIAM Project.

The second annual meeting, an instance that was held on November 10th through a meeting via Zoom (Figure 4.b). The initial kickoff was given by Dr. Gladys Vidal, CRHIAM Director, who showed the progress of the Center in the last year, the incorporation of new researchers, the new dissemination products that have been developed-infographics, policy briefs, among others-, and the challenges that are looming in the face of the continuity project.

The second presentation was made by Sebastián Jofré, Head of the Department of Aquatic Ecosystems of the Ministry of the Environment, where he presented the work carried out in this department and the possible areas of collaboration between CRHIAM and the ministry.

At the meeting, the contribution and legacy of Dr. Fernando Concha, first director of the Center, professor of the Department of Metallurgical Engineering and Professor Emeritus of the University of Concepción, who passed away at the beginning of August, was also remembered.

The meeting concluded with a space for conversation that sought strategies to connect the work developed by CRHIAM with the external environment and society in general.

a)

b)

Figure 4. Advisory Council members. a) June 16th meeting and b) November 10th meeting.

2.6 Our Researchers

CRHIAM's research staff is made up of principal, associate and adjunct researchers. These researchers analyze various issues related to the use and care of water resources for agriculture and mining. They carry out activities both in the field and in academia, generating scientific publications and disseminating knowledge to the community. Each researcher is assigned a main Research Line (RL), although they also contribute to the development of CRHIAM's other research lines with the objective of carrying out interdisciplinary work.

Academic Council & Principal Researchers

Gladys Vidal (Director)

RL4: Technology for water treatment and environmental remediation.
Doctorate in Chemical Sciences, Universidad de Santiago de Compostela, Spain.
Industrial Engineering with a Minor in Agroindustry, Universidad de la Frontera, Chile.

Pedro Toledo (Deputy Director)

RL2: New water sources for agriculture, mining and communities.
Doctorate in Chemical Engineering, University of Minnesota, USA.
Chemical Engineering, Universidad de Concepción, Chile.

Diego Rivera

RL1: Efficient use of water in agriculture and mining.
Doctorate in Agricultural Engineering, Universidad de Concepción, Chile.
Civil Engineering, Universidad de Concepción, Chile.

José Luis Arumí

RL5: Water governance, ecosystem services and sustainability.
Doctorate in Engineering, University of Nebraska, Lincoln, USA.
Civil Engineering, Universidad Técnica Federico Santa María, Valparaíso, Chile.

María Cristina Diez

RL4: Technology for water treatment and environmental remediation.
Doctorate in Food Sciences, Universidad Estatal de Campinas, SP, Brazil.
Laboratory Chemistry, Universidad de Chile, Chile.

Roberto Urrutia

RL3: Water availability and quality for agriculture and mining under climate change.
Doctorate in Environmental Sciences, Universidad de Concepción, Chile.
Biology, Universidad de Concepción, Chile.

Leopoldo Gutiérrez

RL1: Efficient use of water in agriculture and mining.
Doctorate in Mineral Processing, University of British Columbia, Canada.
Metallurgical Engineering, Universidad de Concepción, Chile.

Ricardo Barra

RL5: Water governance, ecosystem services, and sustainability.
Doctorate in Environmental Sciences, Universidad de Concepción, Chile.
Biochemistry, Universidad de Concepción, Chile.

Associate Researchers

Alex Godoy

RL1: Efficient use of water in agriculture and mining.
Doctorate in Engineering Sciences with a mention in Chemical Engineering and Bioprocesses, Pontificia Universidad Católica de Chile, Chile.
Bioprocess Biology, Pontificia Universidad Católica de Chile, Chile.

Amaya Alvez

RL5: Water governance, ecosystem services and sustainability.
Doctorate in Law, York University, Canada.
Law, Universidad de Concepción, Chile.

David Jeison

RL4: Technology for water treatment and environmental remediation.
Doctorate in Environmental Sciences, Wageningen University, Netherlands.
Biochemical Civil Engineering, Pontificia Universidad Católica de Valparaíso, Chile.

Eduardo Holzapfel

RL1: Efficient use of water in agriculture and mining.
Doctorate in Water Resources Engineering, University of California, USA.
Agricultural Engineering, Universidad de Concepción, Chile.

Fernando Betancourt

RL1: Efficient use of water in agriculture and mining.
Doctorate in Applied Sciences with a mention in Mathematical Engineering, Universidad de Concepción, Chile.
Chemical Civil Engineering, Universidad de Chile, Chile.

Fernando Concha (RIP)

RL1: Efficient use of water in agriculture and mining.
Doctorate in Metallurgical Engineering, University of Minnesota, USA.
Chemical Civil Engineering, Universidad de Concepción, Chile

Jorge Rojas

RL5: Water governance, ecosystem services and sustainability.
Doctorate in Sociology, University of Hannover, Germany.
Sociology, Institute of Sociology, University of Hannover, Germany.

José Luis Campos

RL4: Technology for water treatment and environmental remediation.
Doctorate in Chemical Sciences, Universidad de Santiago de Compostela, Spain.
Chemical Sciences, Universidad de Santiago de Compostela, Spain.

Mario Lillo

RL1: Efficient use of water in agriculture and mining.
Doctorate in Computer Science, Universidad Politécnica de Madrid, Spain.
Electrical Civil Engineering, Universidad de Concepción, Chile.

Octavio Lagos

RL1: Efficient use of water in agriculture and mining.
Doctorate in Engineering, University of Nebraska, Lincoln, USA.
Agricultural Civil Engineering, Universidad de Concepción, Chile.

Olga Rubilar

RL4: Technology for water treatment and environmental remediation.
Doctorate in National Resource Sciences, Universidad de La Frontera, Chile.
Environmental Engineering, Universidad de la Frontera, Chile.

Pablo Cornejo

RL4: Technology for water treatment and environmental remediation.
Doctorate in Agrarian Biology, University of Granada, Spain.
Agricultural Engineering, Universidad de La Frontera, Chile.

Raimund Bürger

RL1: Efficient use of water in agriculture and mining.
Dr. rer. nat., Mathematik, Universität Stuttgart, Germany.
Diplom-Mathematiker, TU Darmstadt, Germany.

Ricardo Figueroa

RL5: Water governance, ecosystem services and sustainability.
Doctorate in Biological Sciences, Universidad de Málaga, Spain.
Biology Education, Universidad de Concepción, Chile.

Ricardo Oyarzún

RL3: Water availability and quality for agriculture and mining under climate change.
Doctorate in Engineering Science, Washington State University, USA.
Agriculture Engineering, Universidad de La Serena, Chile.

Roberto Ponce

RL5: Water governance, ecosystem services and sustainability.

Doctorate in Science and Management of Climate Change, Ca'Foscari University, Italy.

Business, Universidad de Concepción, Chile.

Lina Uribe

RL1: Efficient use of water in agriculture and mining.

Doctorate in Metallurgical Engineering, University of Concepción.

Materials Engineer, University of Antioquia, Colombia.

Yannay Casas

RL4: Technology for water treatment and environmental remediation.

Doctorate in Applied Biological Science, Ghent University, Belgium.

Chemical Engineer, Marta Abreu de Las Villas Central University, Cuba

Adjunct Researchers

Patricio Neumann

RL4: Technology for water treatment and environmental remediation

Doctorate in Environmental Sciences, Universidad de Concepción, Chile.

Environmental Engineering, Universidad de la Frontera, Chile.

Ricardo Jeldres

RL2: New water sources for agriculture, mining and communities

Doctorate in Engineering Sciences with a mention in Chemical Engineering, Universidad de Concepción, Chile.

Chemical Civil Engineering, Universidad de Concepción, Chile.

Roberto Rozas

RL2: New water sources for agriculture, mining and communities

Doktor rer. Nat. Institut für Physikalische Chemie, Universität zu Köln, Alemania.

Chemical Civil Engineering, Universidad de Concepción, Chile.

Robinson Torres

RL5: Water governance, ecosystem services and sustainability

Doctorate in Environmental Social Science, Arizona State University, USA.

Sociology, Universidad de Concepción, Chile.

Postdoctoral Researchers

Gonzalo Quezada
Universidad de Concepción

Christian Santander
Universidad de La Frontera

Edward Hermosilla
Universidad de La Frontera

Javiera Parada
Universidad de La Frontera

Loretto Arriagada
Universidad del Desarrollo

Stefania Short
Universidad de La Frontera

Rebeca Martínez
Universidad de Concepción

Omar Alvarado
Universidad de Concepción

Eduardo Ortega
Universidad Adolfo Ibáñez

Lucía Scaff
Universidad de Concepción

Camilo Souto
Oregon State University

Julio Careaga
Universidad de Concepción

Francisca Valenzuela
Universidad de Concepción

Samira Hozhabr
Universidad de Talca

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3 Achievements of our work during 2022

3.1 Our research in numbers

Our research lines (RL1 to RL5) have been consolidated during the period under the principles of water security and associated work. In 2022 RL1 to RL5 have been further strengthened by interdisciplinary work, including two major interdisciplinary projects that connect all researchers from all CRHIAM research lines: a) the CRHIAM Communication Series, which is intended to mobilize scientific evidence to stakeholders and society in general, and b) the project "Technologies, CRHIAM methodologies, and guide to best practices for water sustainability in the mining and agricultural industries," the objective of which is to generate methodologies and techniques related to water management for communities, agriculture and mining. This work has provided a better understanding of water resources from an interdisciplinary perspective and reinforced the need to generate a robust institutional framework to support our responses to climate change, the effects of are increasingly extreme in Chile. CRHIAM also promotes interdisciplinary work through scholarships for postdoctoral researchers, since according to the competition rules, the two supervising researchers must come from two different RLs. Thus, the Center's fund granting policy commits us interdisciplinary work.

Figure 5 shows CRHIAM's performance during 2022 compared to baselines set by FONDAP. The effort and solid commitment of CRHIAM researchers are reflected in the results of CRHIAM's ninth year of operation. The number of published papers was 24.3% higher than expected for this period (87 papers indexed in WoS from December 2021 to November 2022). Moreover, the average impact factor was 4.93 (expected value of 2.8 for 2022). In addition, 88.5% of the publications were published in Q1/Q2 journals. CRHIAM's H-index is 36. Meanwhile, advanced human capital training exceeded the expected value, as there are 14 postdoctoral researchers (expected value: 10) actively working, and numerous students graduated during 2022: 12 PhD students, 13 master's students, and 51 professionals/undergraduates. CRHIAM has extended its "establishing collaborative networks" and "dialogue, outreach and technology transfer" efforts using social networks. It is also important to highlight that, as in all previous years, a 2-day meeting was held with CRHIAM students, during which they all presented their work in an atmosphere of dialogue and friendship.

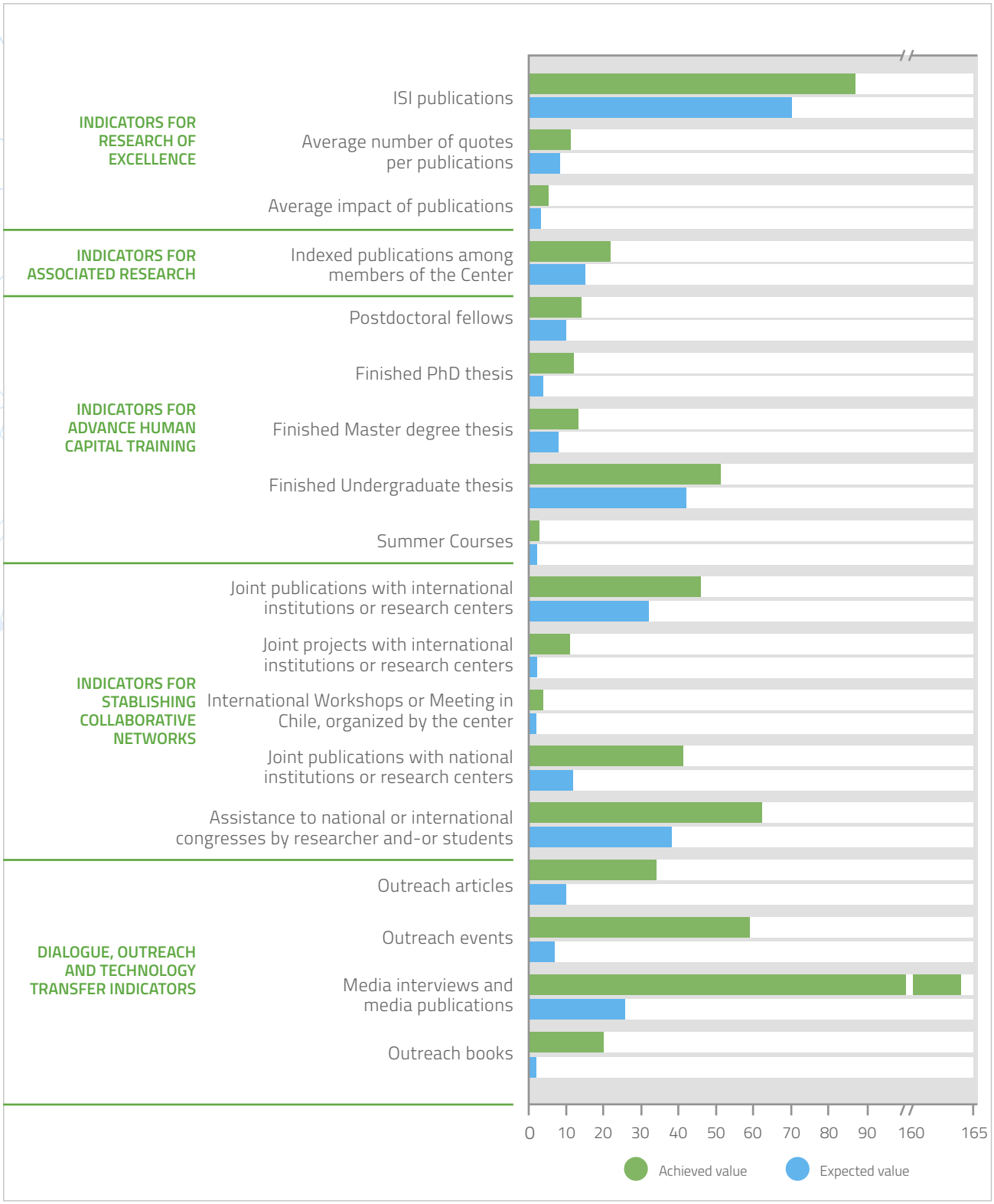


Figure 5. Selected CRHIAM indicators for year nine.

This report shows that CRHIAM has maintained a strong national presence through its dissemination of results, co-organization of congresses and seminars, delivery of a new version of the CRHIAM Water Resources for Sustainable Development diploma course and others, opinion columns, dissemination of scientific evidence in specialized columns, and new agreements with public and private sector stakeholders and foundations, among other activities. Specifically, CRHIAM is working on the co-organization of congresses (i.e.: Water Congress 2022 and International Atmospheric Rivers Conference 2022, among others); the CRHIAM Lecture Cycle (held monthly); and CRHIAM 2022 book launches, held virtually via specific platforms or Facebook Live. In addition, CRHIAM students, as in previous years, are participating online in international congresses and national and international courses and seminars.

Regarding "establishing collaborative networks" and "dialogue, outreach and technology transfer," in 2022 an effort was made to draw more attention to CRHIAM members' work, research, and contributions to public policies and society. The results included communication inside the Center and with its stakeholders and the national and international community in general. the above is presented in later sections.

3.2 CRHIAM: Joint and Interdisciplinary Work

In 2022 there has been an emphasis on joint work through research projects. Work is being done on the project "Technologies, CRHIAM methodologies, and guide to best practices for water sustainability in the mining and agricultural industries," the objective of which is to generate methodologies and techniques related to water management for communities, agriculture, and mining. This work has strengthened our understanding of water resources from an interdisciplinary perspective and reinforced the need to generate a robust institutional framework to support responses to climate change, the effects of which are increasingly extreme in the country. In addition, a significant portion of CRHIAM researchers participated in the fourth version of the Water Resources for Sustainable Development diploma course, offered online. This multi- and interdisciplinary course is led by principal and associate researchers. It includes four teaching modules: 1) Climate change and ecosystems and their effects on water resources, 2) Production processes, communities, and water resources, 3) Water technology for sustainability, and 4) Conflicts over water and institutions and instruments for water resource management in Chile.

The metric for evaluating synergy and collaboration among research lines is the number of joint WoS publications. Here we considered publications having two or more (co-) authors from different research lines (interdisciplinary) and within the same research line (synergy), both presenting as collaboration among research lines. It should be noted that each research line is composed, by design, of researchers from different disciplines. Table 1 shows the collaboration among the center's members and among research lines. In 2022 the center published 87 papers indexed in WoS. Of the WoS papers, 25.3% were co-authored by members of the center and 18.4% were co-authored by members of the same RL. Besides that, there are six WoS publications where there are authors from different lines of research, in which there is one publication where 3 CRHIAM's RLs are present.

Table 1. Summary of intra- and inter-RL publications in the 2022 period

	RL1	RL2	RL3	RL4	RL5
RL1	19[&](5*)	1	2	1	0
RL2		11(2*)	0	0	0
RL3			7(0*)	0	1
RL4				34(7*)	0
RL5					10(2*)

RL: CRHIAM Research Line
RL1: Efficient use of water in agriculture and mining; **RL2:** New water sources for agriculture, mining, and communities; **RL3:** Water availability and quality for agriculture and mining amid climate change; **RL4:** Technology for water treatment and environmental remediation; **RL5:** Water governance, ecosystem services and sustainability.
&The first number in the diagonal of the matrix indicates the total WoS publications of the RL.
*WoS publications with two or more CRHIAM researchers from the same research line as authors.

The periodic publication of CRHIAM Communication Series volumes has fostered significant multidisciplinary work. Each publication uses plain language to disseminate the scientific achievements of the center's members, but also contributes to the current discussion on water issues in Chile. In 2022 CRHIAM has published volumes on 17 different topics: "Phosphorus as a nutrient: global, environmental perspectives and its application in agriculture," "Mining 4.0," "Basin vulnerability: Stressors and challenges," "Lithium, Strategic resource? To know and tell," "Environmental quality of drinking water sources from sanitary service companies in Chile. 2014-2020 period," "Hydrological modeling to face global changes," "Comparative study of the regulation of rainwater harvesting," and "Quality of recirculated water in mining operations. Improvement through chemically functionalized glass microspheres," among others. Table 2 summarizes the collaboration among the Center's members and among research lines.

Table 2. Synergy among CRHIAM researchers in the publication of CRHIAM Communication Series volumes, 2022

	RL1	RL2	RL3	RL4	RL5
RL1	0[&](0*)	6	2	3	4
RL2		0(5*)	0	0	0
RL3			0(2*)	0	0
RL4				0(1*)	1
RL5					0(1*)

RL: CRHIAM Research Line
RL1: Efficient use of water in agriculture and mining; **RL2:** New water sources for agriculture, mining, and communities; **RL3:** Water availability and quality for agriculture and mining amid climate change; **RL4:** Technology for water treatment and environmental remediation; **RL5:** Water governance, ecosystem services and sustainability.
&The first number in the diagonal of the matrix indicates the total CRHIAM Communication Series of the RL.
*Communication Series with CRHIAM researchers from the same research line as authors.

Also, during 2022 CRHIAM published a new product "CRHIAM Policy Briefs" to generate guidelines for public institutions in short documents (3-6 pages). This new product was also designed to reinforce the synergistic work between the Center's researchers and generate documents with an interdisciplinary perspective, thus contributing to public institutions in the face of water scarcity and climate change problems. During the year 2022, 9 short documents were launched, which mobilize scientific evidence to main points to be considered by public institutions.

3.3 Developing Human Capital in Water Resources

Within the four objectives, the CRHIAM Fondap Center has committed itself to the training of human resources at the undergraduate level – supporting thesis projects – and especially at the graduate and postdoctoral levels, to generate a critical mass that will support the development of capacities in water resources. CRHIAM, through its principal, associate, and adjunct researchers, offers both graduate (PhD and master's) and undergraduate programs. CRHIAM is currently in its ninth year as a project and is proud to have become a human capital training center. In its first nine years of operation (2014-2022), the center worked with 1507 students (undergraduate and graduate) and postdoctoral researchers from different schools of the Universidad de Concepción, Universidad del Desarrollo, Universidad de La Frontera, Universidad de La Serena, Universidad Adolfo Ibáñez, Pontificia Universidad Católica de Valparaíso, Universidad de Antofagasta, Universidad del Bío-Bío and Universidad de Talca.

Figure 6 shows information on the students (undergraduate and graduate) and postdoctoral researchers connected to CRHIAM through its researchers and/or scholarships granted by the center; the information is presented in cumulative terms and by year, which allows a comparison with 2022. In 2022, 115 undergraduate students, 74 graduate students (25 master's and 49 doctoral) and 14 postdoctoral researchers have worked with CRHIAM. All this information is up to December 2022.

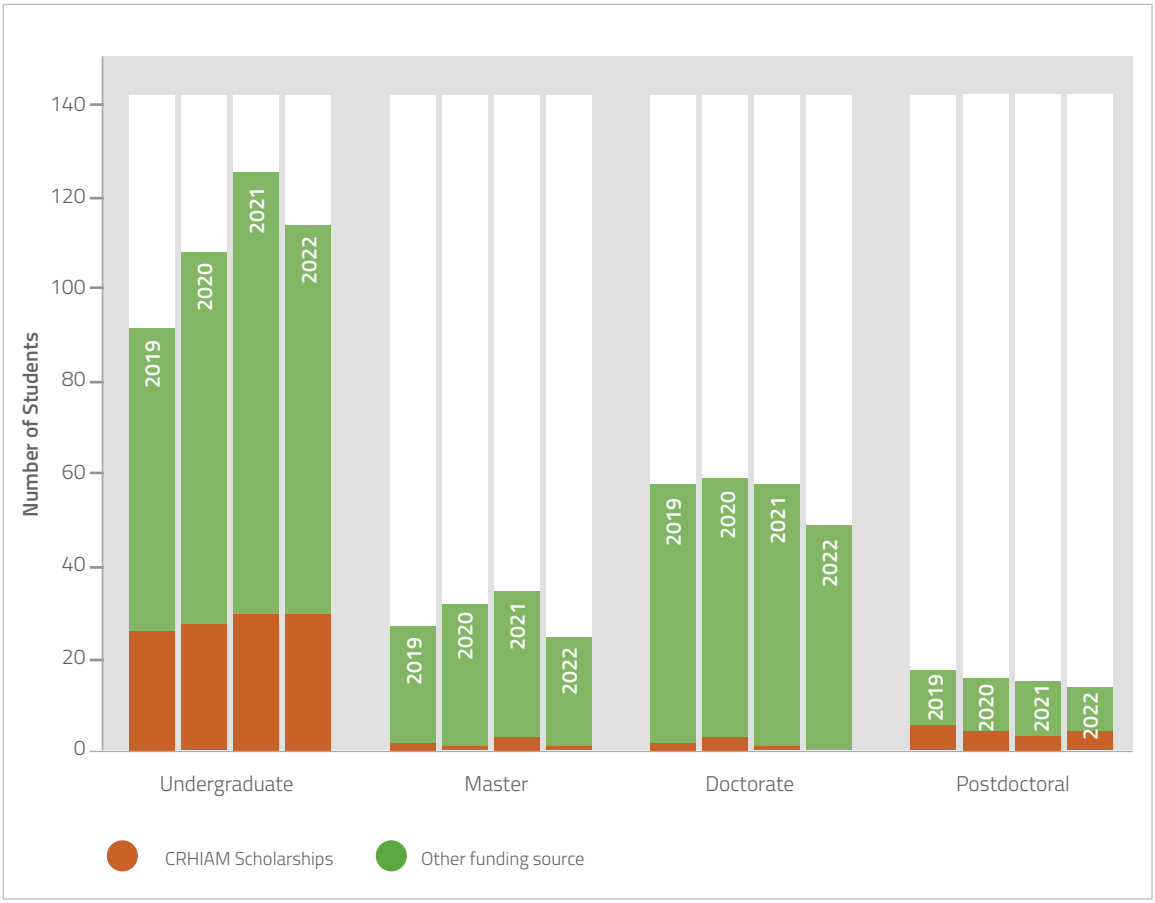


Figure 6. Number of postdoctoral fellows and graduate and undergraduate scholarships.

Below is a list of 2022 CRHIAM scholarship students in the different academic degree programs: postdoctoral researchers, master's and undergraduate students.

Table 3. Postdoctoral researchers funded by CRHIAM during 2022

Name	Research Topic	Advisor Name	Institution
Camilo Souto Escalona	Effects of the use of new technologies for the quantification of water requirements in fruit trees for irrigation design and management purposes	Eduardo Holzapfel and Gladys Vidal	Oregon State University / Universidad de Concepción
Eduardo Ortega Martínez	Removal of nitrates from groundwater in bioelectrochemical systems: impact of ionic strength	José Luis Campos and Ricardo Oyarzún	Universidad Adolfo Ibáñez
María Lucía Scaff Fuenzalida	Characterization of storms associated with atmospheric rivers in the South Central zone of Chile and their impact on water security	Mario Lillo and Ricardo Oyarzún	Universidad de Concepción
Francisca Valenzuela Aguayo	Genetic monitoring and its applications in the evaluation of the quality of the water resource in a basin with intense agricultural use	Jorge Rojas and Mario Lillo	Universidad de Concepción

Table 4. 2022 CRHIAM master's scholarship students

Name	Thesis Title	Advisor Name	Degree-Conferring University
Jahir Ramos Ibáñez	Improvement of flocculation of clayey tailings in seawater managing the physicochemical characteristics of the polymer	Ricardo Jeldres and Fernando Betancourt	Universidad de Antofagasta

Table 5. 2022 CRHIAM undergraduate scholarship students

Name	Thesis Title	Advisor Name	Degree-Conferring University
Carlos Campos Sáez	Reservoir-type hydroelectric development in the Bíobío region and its relationship with greenhouse gases, CO_2 and CH_4	Ricardo Figueroa	Universidad de Concepción
Carolina Sepúlveda Jara	Mapuche worldview on water, nature and territory: Coloniality, forest extractivism, and metabolic fractures in the Chol-Chol and Lumaco river basin, Araucanía Region	Robinson Torres	Universidad de Concepción
Daniel Lewis Gozalvo	Biological removal of phosphorus in effluent from the kraft pulp industry	Gladys Vidal	Universidad de Concepción
Daniel Reyes Pasmiño	Comparative study of the influence of rheology through the use of rheology modifiers on the classification and recovery of particles in a 3-inch hydrocyclone	Fernando Betancourt	Universidad de Concepción
Javiera Gutiérrez Henríquez	Evaluation of the behavior of organic matter and salinity in gray waters treated through a constructed wetland of subsurface vertical flow	Gladys Vidal	Universidad de Concepción
Josefina Burgos Flores	Evaluation of the effect of antibiotic loads on the stability parameters of an activated sludge system used for wastewater treatment	Gladys Vidal	Universidad de Concepción
Karina Painenao Martínez	Characterization of nature-based solutions focused on the new climate change law	José Luis Arumí	Universidad de Concepción
María Monserrat Sabag	Evaluation of the quality of reclaimed water from membrane processes and built wetlands through bioindicators of endocrine disruption, for reuse in groundwater	Gladys Vidal	Universidad de Concepción

Table 5 (cont.). 2022 CRHIAM undergraduate scholarship students

Name	Thesis Title	Advisor Name	Degree-Conferring University
Nikole Guerrero Zúñiga	Comparative evaluation of the reactivation of pathogenic microorganisms contained in an effluent treated by activated sludge vs an effluent from a constructed wetland, after being subjected to a UV disinfection treatment	Gladys Vidal	Universidad de Concepción
Matías Campos Garagay	Application of the Polymerase Chain Reaction (PCR) technique for the identification of microcystin-producing cyanobacteria	Roberto Urrutia	Universidad de Concepción
Yhoely Fariña Martínez	Comparison of the presence of *Escherichia coli* in the Pemuco and Dollinco estuaries, evaluating the conditions of both basins	José Luis Arumí	Universidad de Concepción
Blanca Becerra León	Study of the effect of operational sintering modifications on the evolution of crystalline and amorphous phases of ceramic foams made from mine tailings	Lina Uribe	Universidad de Talca
Lisette Lagos Aguilar	Effect of the presence of mineral particles on coalescence events in a dynamic bubbling system	Pedro Toledo and Jorge Saavedra	Universidad del Bío-Bío
Benjamín Garnica Subiabre	Potential assessment reuse of gray water laundry in agriculture, treated by a flow constructed wetland subsurface vertical	Gladys Vidal	Universidad de Concepción
Camila Cerda Vega	Origin, presence and mobility of metals and metalloids in water underground: analysis conceptual and situation associated with systems rural toilets in the province of Limarí	Ricardo Oyarzún	Universidad de La Serena

Table 5 (cont.). 2022 CRHIAM undergraduate scholarship students

Name	Thesis Title	Advisor Name	Degree-Conferring University
Camila Vásquez Chávez	Approach to the study of microbiome information of surface waters of the Biobío river and its relationship with environmental variables	Ricardo Figueroa	Universidad de Concepción
Catalina Rojas Rodríguez	Stability and coalescence of bubbles in brines hyper-focused on one bubble column: type effect and concentration of sparkling	Pedro Toledo and Jorge Saavedra	Universidad de Concepción
Catalina Jara Espinoza	Evaluation of the pesticide degradation in a system of biopurification inoculated with a mushroom consortium immobilized	María Cristina Diez	Universidad de La Frontera
Diego Arriagada Manosalva	Diagnosis of Water Organizations rural drinking	José Luis Arumi	Universidad de Concepción
Estefanía Morán Henríquez	Irrigation management in cherry trees	Eduardo Holzapfel	Universidad de Concepción
Jazmín Veloso Sepúlveda	Effect of irrigation with production effluents cellulose in worms terrestrial	Roberto Urrutia	Universidad de Concepción
Joaquín Araya Vera	Assess change in toxicity from pulp effluent treated with procedure advanced oxidation in agricultural crops	Roberto Urrutia	Universidad de Concepción
Kimberly Fuentes Rojas	Evaluation of methods of calculation and estimation of mass flow of constituents selected in rivers of the Coquimbo region	Ricardo Oyarzún	Universidad de La Serena
Matías Espinosa Navarro	Evaluation of the use of vegetable oils waste from different sources like sulphide collecting reagent coppermade	Lina Uribe	Universidad de Talca
Omar Zapata Umaña	Quality characterization of surface water and underground along the Huasco river	José Luis Arumí	Universidad de Concepción

Table 5 (cont.). 2022 CRHIAM undergraduate scholarship students

Name	Thesis Title	Advisor Name	Degree-Conferring University
René Sepúlveda Jara	Product evaluation of satellite precipitation using the model SWAT hydrological	José Luis Arumí	Universidad de Concepción
Sara Vargas Villalobos	Quality characterization of water from rivers in the center northern Chile through the use of indicators quality	Ricardo Oyarzún	Universidad de La Serena
Héctor Lizama Ailio	Recovery of ultrafine particulate material by flotation in saline waters through optimization of reagent conditioning	Leopoldo Gutiérrez	Universidad de Concepción
Francisco Fuentes Molina	Socio-environmental conflict and social movements for the recovery of the territories of life, water, and good living in the community of Coronel	Robinson Torres	Universidad de Concepción
Fernanda Sepúlveda Fernández	Analysis of methods of evaporation reduction in bodies of water	Octavio Lagos	Universidad de Concepción

Water Resources for Sustainable Development Diploma

This is the fourth year that CRHIAM has offered the Water Resources for Sustainable Development Diploma course and the third year that it has been delivered as an e-learning course. The program aims to provide an update to professionals working in different sectors who need a current, interdisciplinary vision of water resources. Table 6 shows the components of the Water Resources for Sustainable Development program.

Table 6. Water Resources for Sustainable Development program components

MODULE	TEACHERS	HOURS
MODULE 1 Climate change, ecosystems and their effects on water resources.	Dr. Alberto Araneda	4
	Dr. Ricardo Figueroa	5
	Dr. José Luis Arumí	4
	Dr. Ricardo Figueroa	5
MODULE 2 Production processes, communities and water resources.	Dr. Pedro Toledo	4
	Dr. Leopoldo Gutiérrez	5
	Dr. Diego Rivera Dr. Eduardo Holzapfel	4
	Dr. Carolina Baeza	5
	Dr. Patricio Neumann	4
MODULE 3 Water technology for sustainability.	Dr. Gladys Vidal	5
	Dr. (c) Ana María Leiva	4
	Dr. Daniela López	4
	Dr. Gladys Vidal	5
MODULE 4 Water conflicts, institutions and instruments of water resources management in Chile.	Dr. Amaya Alvez - Rodrigo Castillo	5
	Rodrigo Castillo	4
	Dr. José Luis Arumí	4
	Dr. Ricardo Barra	4
	Dr. Jorge Rojas	3
COURSES		
Course 1: Formulation of projects for innovation under climate change	Marcela Cabezas, MSc.	6
Course 2: Elective	Elective supervisor	6

The class of 2022 included 22 professionals from different backgrounds (Table 7): engineers in various fields (civil, environmental, agricultural, biotechnology, forestry, and management), lawyer, and marine biologists, among others. In addition, thanks to its online delivery, the new students attended from different cities throughout the country, including Iquique, Santiago and Puerto Montt. Each study module is led by CRHIAM researchers from the Schools of Engineering, Agricultural Engineering, Environmental Sciences, Legal and Social Sciences, and Social Sciences, all with extensive experience in water resources; guest lecturers further enrich the curriculum. A total of 91 professionals have updated their knowledge with CRHIAM in the last 4 years.

Table 7. Water Resources for Sustainable Development certification program class of 2022

NAME	PROFESSION OR ACADEMIC BACKGROUND
Varoliza Aguirre Ortiz	Lawyer
María Elena Bizarro Conejeros	Environmental Engineer
Paula Calderón Riquelme	Agricultural Civil Engineer
Diego Carrasco Pinto	Civil Engineer in Biotechnology
Tiffany Cataldo Estay	Degree in Marine Biology
David Cortés Tapia	Agricultural Execution Engineer
Mauricio Durán Urra	Civil Engineer
Juan Espinoza Gómez	Agricultural Engineer
Fernando Flores Mallea	Execution Engineer in Business Administration
Marcelo Jiménez Novara	Agricultural Civil Engineer
Eduardo Mella Sepúlveda	Degree in Engineering Sciences
Judith Mendoza Espínola	Agricultural Engineer
Diego Muñoz González	Civil Engineer
Claudio Peñaloza Hebles	Civil Engineer
Aldo Ríos Segura	Forestal Engineer
Camilo Rivera Carvajal	Metallurgy Technologist

Table 7 (cont.). Water Resources for Sustainable Development certification program class of 2022

NAME	PROFESSION OR ACADEMIC BACKGROUND
Leonardo Saavedra Rodríguez	Marine Biologist
Ricardo Sepúlveda Muñoz	Civil Engineer
Carolina Torres Durán	Social Worker
Andrés Ulloa Alvarado	Civil Engineer
Daniela Valdés Paniagua	Environmental Civil Engineer
Víctor Zúñiga Pérez	Anthropologist

The official welcome to the new students (generation 2022) took place on April 13th, when they were able to introduce themselves and meet the diploma coordinating team. Figure 7 shows the students who participated in the e-learning version (2022) of the program led by the Center.

Figure 7. Water Resources for Sustainable Development Diploma program class of 2022.

The 22 professionals who were part of the fourth version of the Water Resources for Sustainable Development Diploma course officially concluded their studies with a virtual closing ceremony (Figure 8). The meeting was held on July 15th and provided an opportunity to talk with the students and learn about their experiences and opinions of the program and what it meant for them to take it online.

Figure 8. Virtual closing ceremony for the 2022 version of the program.

CRHIAM

CENTRO DE RECURSOS HÍDRICOS PARA LA AGRICULTURA Y LA MINERÍA

ANID/FONDAP/15130015

Annual **Report** 2022

4 The work of our research lines

4.1 RL1. Efficient use of water in agriculture and mining

This research line contributes to water security by addressing different dimensions of water security and different uses. Research in agriculture focuses on efficient use of water and information technologies, along with data analysis in complex hydro-economic systems. For mining the focus is on improving water recovery in copper concentrators. We are hosting two postdoctoral fellows working on new technologies for water management in fruit orchards (with Oregon State University) and hydrometeorological characterization of storms in south-central Chile to understand the climate-water-agriculture continuum. We are also hosting two doctoral students working on socio-hydrological agent-based modeling to assess future water conflicts at basin scale and optimization techniques in agricultural water management. At the undergraduate level, there are 10 students working on their theses. Since November 2021, the team has submitted five FONDECYT proposals (totaling 750 kUSD), one FONDEF proposal (250 kUSD), and one FONDEQUIP proposal (1000 kUSD). All the proposals are directly related to results from previous years. We have also maintained collaboration to advance in the understanding of streamflow generation in the Andes, focusing on the supply to agriculture through and Anillo project entitled "Cold-blooded: drivers of climate change refugia for glaciers and streamflow responses," which is linked to the second and fourth specific goals: to evaluate the relationship between geomorphometric changes and glacier-climate sensitivity and to establish the role of glaciers within CCR in mountain watersheds in downstream baseflow.

Agriculture

The water demand group contributes to research on water security by improving water efficiency, from plot to watershed scale. Most of the research time has been devoted to field data collection. We made important contributions to policymaking by participating in high-level panels such as IPCC and IPBES. Indeed, one colleague is now Visiting Scholar, Weatherhead Scholars Program, Weatherhead Center for International Affairs at Harvard University. The following Important projects are being carried out: Optimization of applied water and yield estimation. In Santana *et al.* (2022) we presented an experimental method to measure small-magnitude forces with a strain gauge as a force sensor in the fluid–wall interaction of open water channels, with potential application in the improvement of furrow irrigation design. Carrasco-Benavides *et al.* (2022) proposed a method for implementing the water footprint, while Portuguez-Maurtua *et al.* (2022) assessed different methods of filling gaps in daily precipitation data using regression model (RM) and machine learning (ML) techniques Catchment scale water management. We have expanded our research to upper catchments that feed downstream uses. We carried out scientific and technological research on socio-hydrological agent-based modeling, in which the multiple dimensions and stakeholders involved in water management are represented

and interact with each other, and which could anticipate future water conflicts. Martínez-Retureta *et al.* (2022) approached how land-use/cover change (LUCC) and climate change (CC) affect water resource availability as they alter important hydrological processes using RegCM4-MPI-ESM-MR and SWAT. In the same line, Balocchi *et al.* (2022) analyzed changes in hydrological responses in three catchments in terms of pre- and post-fire mean residence time. Tritium concentrations indicated water ages from 5 to 30 years.

Mining

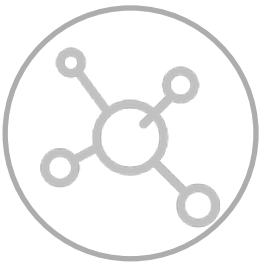
The chilean mining industry is facing various challenges, including shortages of strategic resources such as water, the need to comply with the restrictions imposed by society and environmental regulations to carry out its productive operations, and the effects associated with the complexity of the minerals to be processed, among others. Therefore, chilean public policies are promoting green mining. CRHIAM's activities are aligned with the development of green mining for our country. Important projects that are being carried out are described below.

I) Mathematical modeling

A first project on mathematical modeling of flotation processes *(researchers R. Bürger, F. Betancourt, L. Gutiérrez, A. Ramírez, L. Uribe; student Yolanda Vásquez, PhD program on Mathematical Engineering, Universidad de Concepción)* is ongoing. In this project, models of the columnar flotation process have been proposed, each with a different degree of complexity. In parallel, a pilot-scale flotation column was designed with the aim of validating the developed models. Preliminary results indicate that the models are capable of replicating the qualitative behavior of the process. A mathematical workshop on modelling and simulation for bioprocesses, wastewater treatment, and mineral processing was held (July 5-6); it included a speaker from the JRI Engineering company and the participation of a representative of Hibring Ingeniería.

II) Froth flotation

BCR (bubble-conditioning reactor) technology is being developed for the correct conditioning of the reagents used in the flotation of copper and molybdenum minerals to improve recovery in processes that use conventional water and seawater (COPEC UC FUNDATION 2019.R.1150 "BCR technology to improve Cu and Mo repair" project, Gutierrez *et al.*). Previous results showed increases in copper and molybdenum recoveries of more than 5 and 10 percentage points, respectively, and an increase in the quality of water that is subsequently recirculated into the processes is expected. Two important grants have been awarded to scale this technology up (Speed Up Voucher funded by the Integrated Mining Technologies Piloting Center (CIPTEMIN) and $200 million from ANID FONDEF ID22I10102). Another project on flotation is aimed at developing a process for the generation of green reagents based on polysaccharides extracted from wheat straw to improve copper recovery from high clay ores and in seawater (Castillo et al., 2020; FONDEF ID18I10117 Project, Gutierrez *et al.*; Ramirez *et al.*, 2020a; 2020b; patent filed at INAPI. Request Number: 202003090; a patent was GRANTED by INAPI in 2022 on this topic. Request Number: CL201903655).



III) Mechanical operations in mining process

In general, particle size reduction operations can be improved to reduce water and energy consumption in later stages. In this project we study the comminution process in several stages during the mining process: the secondary fragmentation process in the block caving method and fragmentation in the primary and secondary crusher. The processes were modeled from a phenomenological point of view and validated through suitable experiments. Three papers on this topic have been produced (Gomez *et al.*, 2021; Moncada *et al.*, 2021; Castro *et al.*, 2022).

4.2 RL2 - New water sources for agriculture, mining, and communities

The mining industry continues to make great efforts to close the water cycle; however, the "loss" of water to tailing dams remains. Disruptive ideas are needed for new cost-effective solid-liquid separation technologies surgically focused on saving water. The research carried out in 2022 by our research line (RL2) addresses various aspects, with varying degrees of progress, aimed at sustainable use of water with a significant shrinkage of the environmental footprint. The objectives for 2022 have been achieved through a good mix of experienced and young researchers effectively connected with quality centers abroad, with carefully selected students in a suitable research atmosphere. There has been strong, productive collaboration with the other CRHIAM RLs; Chilean universities (Universidad de Antofagasta, Universidad del Bío Bío, Universidad Arturo Prat and Pontificia Universidad Católica de Valparaíso); foreign universities (Aalto University (Finland), Universidad Politécnica de Cartagena (Spain), Universidad Complutense de Madrid (Spain) and Heinrich Heine University (Germany)); the research center SCIRO (Australia); and industry partners. Interdisciplinary work with researchers from RL2, RL3, and RL5 stands out. An account of the 2022 results follows.

I) Artificial vision and machine learning for the analysis of bubble coalescence in dynamic flow processes

The coalescence of air bubbles in a liquid phase deteriorates the efficiency of numerous industrial processes such as froth flotation, wastewater treatment, etc. Bubble coalescence begins with the thinning of the liquid between the bubbles until it becomes a thin film that eventually breaks. A gas neck forms between the coalescing bubbles, and as the neck expands both the surface area and the curvature of the resulting bubble decrease. The vast majority of studies focus on the coalescence of two bubbles in the absence of interactions with many bubbles as in a typical process (Contreras, 2022). We developed a machine vision system capable of tracking individual bubbles in a bubbling system that contains aqueous solutions of foaming agents and salts, from the entrance of the bubbles to their exit (Solar, 2022). To this end, we used a 960-fps slow-motion recording system, and the collected images were analyzed using particle recognition techniques. Later, this information was processed for bubble tracking based on identification of neighboring particles and the use of machine learning techniques. This allows the positions and velocities of bubbles to be tracked spatially and temporally and access to data on bubble burst frequencies, collision frequencies, coalescence frequencies, area, perimeter, and bubble shape factors, among others. In addition to these properties, it is possible to determine the time for

which two bubbles remain together before coalescing, which we call the true coalescence time. It is of great interest to answer two questions: to what extent does the frequency of bubble collisions affect coalescence events, and to what extent does bubble coalescence determine the mean size of bubbles? The results show that dynamic effects determine much lower coalescence times, suggesting that flotation conditions should be revised if they are based on static times, as non-optimal conditions lead to misuse of water (Solar, 2022; Contreras, 2022; Ulloa, 2022; Solar *et al.*, 2022; Lagos, 2022; Rojas, 2022). Research lines involved: RL1 and RL2

II) Phosphorus control in large bodies of water: Abatement with clays

Excess nutrients under specific environmental conditions allow some species of algae to produce toxins, an event known as harmful algal blooms (HABs). In particular, excess phosphate comes from industrial and domestic wastewater discharged into watercourses and directly into bodies of water, in addition to natural leaching. Thus, there is a need for profitable, ecosystem-friendly treatments for phosphate export from large bodies of water. Gallardo-Rodríguez *et al.* recently thoroughly reviewed the state of the art (Gallardo-Rodríguez *et al.*, 2019). Their main conclusion is that using clays to control the proliferation of phosphates and algae is the most promising method in salt water, particularly in seawater. In fresh water, it may also be necessary to add a polyelectrolyte. Clays are very attractive because they are nontoxic; only sand and local soils could involve less ecological risk (Pan *et al.*, 2011). Various experimental studies have shown that clays effectively adsorb phosphate (Gupta and Bhjattacharyya, 2012; Wei *et al.*, 2014; Mitra and Prakash, 2017); however, the conditions used are so different that the results present a dispersion that makes it impossible to discern the anchoring mechanism of the phosphate ions, much less to quantify the adsorptive potential of the clays in salt water. In our group, we have shown that kaolinite in particular favorably adsorbs water, alkali and alkaline-earth ions, heavy metal ions, simple monomers, sugars, saturated hydrocarbons, and polar organic macromolecules (García, 2021; García *et al.*, 2021). We concluded that experimental and simulation results showed that common clays such as kaolinite can be used to control phosphates in large bodies of water and suggest the adsorption mechanisms, at least at low salt concentrations. In 2021 we continued using the quantitative methodology developed by our group and consolidated in 2020, which is

based on ab initio calculations and molecular simulation techniques (MMT) for the design of process reagents (Quezada *et al.*, 2017; 2018; 2019; 2020; 2021a; 2021b) for studying the adsorption of two species of phosphates that prevail at neutral pH, the dihydrogen phosphate ion and the hydrogen phosphate ion in a 1:1 ratio, on the three principal planes of kaolinite, which include the two basal surfaces (001) and (00) and the edge sites (010), in water as salty as seawater. The adsorption capacity of kaolinite, including all its surfaces, increases with salt concentration, from 22.6 mmol/kg in freshwater to 28.8 mmol/kg in synthetic seawater reagents (García *et al.*, 2022a). These results suggest that using clays to control phosphate in coastal waters can effectively contribute to the sustainability of marine industrial activities and ultimately to public health. We are also advancing in the evaluation of the adsorption capacities of another interesting clay: montrillonite (García *et al.*, 2022b) Research lines involved: RL1, RL2, RL3, RL4, and RL5.

III) In search of a selective collector of lithium-rich spodumene in saltwater using quantum chemistry calculations and molecular dynamics simulations

Several research groups have reported on the utility of using molecular modeling tools for understanding mineral–reagent interactions as a complement to the expensive trial-and-error experiments that are used today and do not ensure optimal results. In our group we showed that molecular modeling (quantum + molecular dynamics) provides a sound method to quantify nano-scale forces at the mineral-water interface (Valenzuela *et al.*, 2016; 2017), crystal structure of minerals (Rozas *et al.*, 2021), and crystal structure specificity of diverse organic molecules for different mineral systems. For example, we quantified the partially-hydrolyzed polyacrylamide (HPAM) specificity for quartz in saltwater (Quezada *et al.*, 2017; 2018; 2020; 2021a), for corundum in saltwater (Quezada *et al.*, 2017), and for kaolinite edges in saltwater (Quezada *et al.*, 2019) and the specificity of sodium oleate for spodumene in saltwater (Quezada *et al.*, 2021b). This last work is incomplete because the structure and charge distribution on the (110) plane of the spodumene, which is the most frequent, was only determined with thermodynamic criteria. However, in 2022 the study, including the kinetic criteria, was completed (Alvarado *et al.*, 2022a; 2022b; 2022c). In the near future this methodology may be implemented so that the computer chooses functional groups from a list and evaluates their performance, as a

spodumene collector in this project, a case of artificial intelligence. The conditions are fixed by the operation, pH between 7 and 8 at room temperature. Saltwater varies in concentration from freshwater to seawater, including the possibility of using seawater directly or partially desalinated. The sizeable computational infrastructure required includes the cluster of our research group and the UDEC Southern GPU-cluster (SGPU-C), funded by FONDEQUIP EQM150134. This year we added a quantum chemist to our group. Research lines involved: RL1 and RL2.

IV) Dry mining... just a naive dream?

In 2014 we started talking about dry mining with the late Fernando Concha and others and dared to present a project to CORFO that was flatly rejected. On August 24, 2022, in Santiago de Chile, the initiatives for sustainable mining were defined with the participation of all the relevant actors, including representatives from the government, mining companies, sanitation companies, universities and technology centers. One of the initiatives is dry mining. Fortunately, we continue to work on this line, particularly on fluidization in air, on two fronts: experimental and simulation. Actually, simulation came first; we started with the development of a mathematical method based on smoothed-particle hydrodynamics (SPH), a computational method used for simulating the mechanics of continuum media, such as solid mechanics and fluid flows, initially developed for astrophysical problems. To date the most refined version of SPH is the finite particle method. In 2021 we developed two methods, the decoupled finite particle method (DFPM) and semi-decoupled finite particle method (SDFPM), both approximations of FPM in which the correction matrices are simplified by neglecting non-diagonal terms, which effectively decouples corrected value calculations for the field variable and its derivatives along each direction (Achim *et al.*, 2021). This method has the advantage of simplifying the corrections and the extension to 3D, and at the same time avoids the problem of ill-conditioned matrices that can occur in the case of free surfaces (Achim *et al.*, 2022). More recently, on the experimental front, we built a fluidization column that separates particles by size. By adjusting conditions, we managed to clearly separate three groups of particles of different sizes (Hermosilla, 2022). Research line involved: RL2.

Results published but not discussed in detail in this report

Such results include species surface distribution and surface tension of aqueous solutions of MIBC and NaCl using molecular dynamics simulations (Alvarado *et al.,* 2022) and several aspects of clay treatment in mineral concentration processes and in thickening processes to recover water (Yepsen *et al.*, 2022; Pérez *et al.*, 2022a; Jeldres *et al.*, 2022; Leiva *et al.*, 2022; Nieto *et al.*, 2022; Quezada *et al.*, 2021c; Soto *et al.*, 2022). Research lines involved: RL1 and RL2.

Major impacts in 2022

Transfer to industry of a pretreatment of li-rich brines (Toledo, 2022). New project on drought (Gutiérrez *et al.*, 2022). Guest editing of special issues of MDPI Journals (Jeldres, 2022a; 2022b; Toledo 2022a; 2022b; Quezada, 2022). Participation in Water Resources for Sustainable Development diploma course as a lecturer (Toledo, 2022c). New Communication Series volumes (Toledo *et al.,* 2022d; 2022e; Pérez *et al.*, 2022b; Pulgar *et al.*, 2022; Concha *et al.*, 2022). Opinion columns (Toledo, 2022f; 2022g). Policy briefs (Toledo and Gutiérrez, 2022; Toledo, 2022h). New academic positions at UBB (Quezada, 2022a).

4.3 RL3 - Water availability and quality for agriculture and mining amid climate change

Inter/transdisciplinary work of RL3 researchers with others RLs

Work has been carried out within the framework of the drought project (ANID project FSEQ210002), which brought together different CRHIAM researchers to speed up the development of methodologies and good design and management practices that will allow for better coping with water scarcity. As part of this project, Drs. Urrutia and Arumí are collaborating with Dr. Toledo (RL2) to develop water treatment solutions that will make it possible to face the growing problem of salinity that affects agriculture in north-central and south-central Chile.

In parallel work, we are searching for new water sources for agriculture through the FIC-Biobío project entitled "Use of cellulose effluents for agricultural irrigation," which is directed by Dr. Urrutia, with Drs. Arumí (RL3, RL5) and Vidal (RL4) collaborating. This project has the support of the region's pulp industry (Celulosa Arauco), which will provide samples of treated effluent for laboratory experiments.

Another aspect of water quality that is being evaluated is the presence of emerging contaminants in freshwater bodies in the Biobío Region. This issue is being addressed through the FONDECYT project "Transboundary movements of plastic waste and the chemical burden from the Biobío River to the Pacific Ocean: How far do they go?" which aims to assess the presence of microplastics in the Biobío River basin and develop a spatial model of the contribution of these pollutants in the coastal area adjacent to its

mouth. In this same area, the presence and environmental effects of silver and titanium nanoparticles in the Biobío River are being evaluated through the completion of the doctoral dissertation of Gester Gutiérrez, a student in the Environmental Sciences doctoral program.

Collaboration with international and national companies

Dr. José Luis Arumí has maintained constant collaboration with different water user organizations in areas related to RL3: i) Research on Laguna Amargo in a project directed by Dr. Denisse Alvarez, in collaboration with Dr. Urrutia and the Longaví River Surveillance Board, and ii) Scientific support for the evaluation of the artificial groundwater recharge program maintained by the Diguillín River Surveillance Board. Dr. Arumí was recently appointed scientific adviser for the technical inspection of the hydrogeological project being developed by the General Water Directorate for the Itata River basin, which is a collaboration model stemming from the previous work developed to study the hydrology of that basin.

Two international master's theses were finished this year: i) That of Asmita Subedi (2022), in collaboration of the Leibniz University Hannover, which focused on water management in the Laja watershed, and ii) that of Luis Alegria, which was submitted to Flinders University in Australia, and studied groundwater recharge in the Diguillín watershed.

Likewise, Dr. Ricardo Oyarzún and Dr. José Luis Arumí participate in the Coordinated Research Project (CRP) "Development and application of isotope techniques for efficient water resources management in mining areas" (Code F33026), the objective of which is "To test and develop capabilities and nuclear methodologies based on the use of isotope hydrology tools for efficient water resources assessment and management in the mining areas in Member States".

Dr. Urrutia has cooperated for almost 20 years with Dr. Nahalie Fagel of the University of Liège through bilateral cooperation projects between Chile and Belgium (Chile/Wallonia-Brussels Mixed Commission), allowing an exchange of researchers and students between the two universities. Within this same cooperation framework, they are preparing a new project aimed at implementing a water quality model to be applied in the Biobío River basin (AGCID, www.agcid.cl).

Contribution of scientific evidence to the country's public policies

Between August and October 2021, Dr. Arumí led the Water and Soil Board within the framework of the Sustainable Forestry and Agricultural Scientific Ministerial Advisory Council, which was a contribution to the publication of the document "Proposal of sustainability indicators for the forestry and agricultural sector in Chile" (Arumí *et al.*, 2022). Dr. Oyarzún participates in the Expanded Committee associated with the development of the Secondary Water Quality Standard for the Elqui River, an initiative led by the Ministry of the Environment (Coquimbo Region). The projects carried out by Dr. Urrutia for the Ministry of the Environment and the General Water Directorate (DGA) on North Patagonian lakes and Lake Lanalhue are aimed at gathering limnological information for the elaboration of a Secondary Environmental Quality Standard for these lacustrine bodies.

RL research topics

Accessibility to information on past environmental and climatic conditions makes an important contribution to any kind of future prediction of global changes. In Chile the amount of past climate information, beyond instrumental records, is limited due to the difficulty of characterizing and quantifying the variability of climatic components with a high resolution. Paleoclimate studies in South America have become highly important due to the scarcity of long-term information available to generate robust climate projections at a regional scale and the importance of forcing (e.g., westerlies) and climatic phenomena (e.g., ENSO, PDO) that can have effects even on a global scale. Thus, the information obtained from lacustrine sedimentary records aids in understanding these phenomena and characterizing past climatic conditions that, in a long-term context, contribute to our knowledge of current global changes. It should be noted that lacustrine sediments are recognized for being excellent archives of environmental changes, with a temporal resolution of sub-decadal scale up to several hundred years (Molenaar *et al.*, 2022; Chandia *et al.*, 2022; Rodriguez *et al.*, 2022). Sedimentary sequences contain indicators that, in general terms, can be grouped into two main types: biological (e.g. diatoms, foraminifera, pollen, ostracods, etc.) and physical-chemical (e.g. density, magnetic susceptibility, granulometry, isotopes, pollutants, geochemistry, etc.) that show climatic, oceanographic, and geological changes, local or regional events, and/or anthropogenic changes.

Amid this backdrop, Dr. Urrutia was awarded the project "Acquisition of an XRF-CS analyzer for the reconstruction of high-resolution climate change in lacustrine and marine sediments" by the FONDEQUIP Medium Scientific and Technological Equipment Competition (2021), which will allow us to increase our knowledge of past climatic conditions by incorporating new environmental proxies in paleolimnological studies, and at the same time contribute to the improvement of future climatic projections for the country.

We continue our work on the determination of water quality parameters of lakes based on the processing of satellite images as a support for the spatial and temporal evaluation and monitoring of ecosystems (Aranda *et al.*, 2021; Barraza *et al.*, 2022; Rodriguez *et al.,* 2022) through the doctoral work of Daniela Rivera, which focuses on developing models to detect and quantify algal blooms in Araucanian lakes.

Regarding hydrological studies, Drs. Arumí and Rivera have made advances in the analysis of forestry hydrology through the doctoral research of Francisco Balocchi, which is focused on the study of hydrological connectivity in the generation of streamflow and the occurrence of minimum flow in watersheds of the coastal mountains (Balocchi *et al.*, 2022). Another advance was published by Portuguez *et al.* (2022), related the use of artificial intelligence to study and complete precipitation data series.

Since April 2021 we have been working on the FONDECYT (1210177) project "A coupled isotopic-geochemical assessment of hydrological dynamics in headwater Andean basins in north-central Chile." This initiative, which is headed by Dr. Oyarzún and includes Dr. Arumí as a co-researcher, involves establishing a robust characterization of hydrological processes in headwater basins by developing an integrated analysis of discharge data and water constituents (chemistry, isotopes) in precipitation and streamflow. The main results were presented at Water Congress (Hernández and Oyarzún, 2021).

4.4 RL4 - Technology for water treatment and environmental remediation

Inter/transdisciplinary work of RL4 researchers

The researchers of RL4 are making efforts to connect the members of the research line and generate products with other research lines. Thus, in 2022 RL4 produced the following CRHIAM Communication Series titles: "Environmental quality of drinking water sources of sanitation service companies in Chile. 2014-2020 period" with professionals from the Chilean Ministry of the Environment, Superintendent of Sanitary Services, and researchers from RL5 and RL3; "Comparative study of the regulation of rainwater harvesting" with RL5 and rainwater harvesting company "Cosecha de Aguas Lluvias"; and "Mathematical modeling of biological systems: microalgae and bacteria for wastewater treatment" and "Phosphorus as a nutrient: global and environmental perspectives and its application in agriculture" both with researchers from RL4 and RL1.

In addition, the ANID FSEQ210002 Drought project entitled "Technologies, CRHIAM methodologies and guide to best practices for water sustainability in the mining and agricultural industries" is connecting researchers from all CRHIAM RLs, particularly R1 and RL4. RL4 is working on the topics "Improving the use of water by plants for food production under osmotic stress" and "Characterization, treatment by vertical subsurface wetlands, and evaluation of the acceptance of reuse of gray water." Meanwhile, the theme of CRHIAM Water Forums 2022 was "Groundwater: Making visible the invisible." This activity took place as part of the celebration of World Water Day and was held on March 18th, 2022, with the participation of researchers from RL1, RL3 and RL4. Topics related to groundwater's role in water security and its size, care and uses were discussed, highlighting the role of soil as a means of providing access to this water reservoir, as well as its primary role in its purification (https://www.youtube.com/watch?v=CkVkrCwn4kQ&t=4s).

RL1 and RL4 are also working on issues of modeling water treatment systems; as part of this work the workshop "Mathematical and modeling simulation for bioprocesses wastewater treatment and mineral processing" was held on July 5-6, 2022. Another result of the modeling and simulation research efforts was the publication in 2022 of a paper on the application of CFD (computer fluid dynamics) to study the behavior of microbial cultures (Sadino-Riquelme *et al.*, 2022). This publication is one of the outcomes of the collaboration relationship established with the University of Alberta, Canada.

Collaboration with foreign and domestic companies

RL4 researchers have several cooperation initiatives with Greece, Argentina, Costa Rica, Germany, Spain, and Brazil, with funds from specific programs for them. RL4 researchers currently maintain international cooperation projects with the University Federal do ABC of Brazil-Chile (ANID/FAPESP 2018/08194-2), Greece-Chile (2019-2022) (ANID/MEC80190057), and Germany (ANID/MEC 80190080). In addition, six Regular and Postdoctoral Fondecyt projects (FONDECYT 1211738, 1181089, and 1191230; FONDECYT

Postdoctorado 3200963, 3190922, and 3180279), three doctoral dissertations, and one master's thesis are currently in progress. With the results obtained from these investigations we want to contribute to science to obtain products that can support companies related to agriculture and the environment. The topics of the projects are: "Network for pesticide risk reduction: New strategies and opportunities," "Nanotechnology for agriculture: new strategies and opportunities and their environmental risk," "Impact of micro-pollutants on the reuse of treated wastewater in scenarios of water scarcity: generation of undergraduate and graduate human capital," and "Strengthening scientific capacities in environmental biotechnology for the protection of water resources from pesticide pollution," among others.

Regarding cooperation with businesses, RL4 researchers are also collaborating with companies to scale the investigated technology. They have a project underway with the EAGON-Lautaro company and Universidad de La Frontera (Temuco) (Araucania Region) to evaluate a Pilot plant for a treatment system for the removal and degradation of wastewater from the chip spray field of the board plant for recirculation purposes. In addition, in 2020-2022 CORFO (the Chilean Corporation for Production Promotion), under the line of social validation, awarded funds for the project "Resilience and adaptability to the water crisis: sponge cities and sustainable fields through wastewater-purifying wetlands." The project will be executed between the Valdivia Wetlands Center (CEHUM) (Los Rios Region), CAREP Rural Cooperative, and CRHIAM, which is acting as the technology accreditation center. In this same line, during the last couple of years work has been done on the development of algae-based treatment systems as a solution for sanitation in small communities. A pilot plant was implemented in the Mapocho-Trebal plant (Agua Andina water company, Metropolitan Region) in the framework of CORFO project 18COTE-98077. Finally, in 2022 the ESSBIO S.A. water company (O'Higgins, Maule, Ñuble and Biobío regions) worked with RL4 to enhance the environmental knowledge of citizen leaders where the company is operating through the course "Water resources management and the urban water cycle," which addressed the effects of climate change on drainage basins, the water cycle, and water quantity and quality.

Contribution of scientific evidence to the country's public policies

In 2022 RL4 has worked hard to ensure the value the research it is carrying out and that its work serves for decision-making in the country. Researchers from RL4 have connected with the Ministry of the Environment and Superintendent of Sanitary Services to evaluate the degradation of the ecosystems that are the sources of drinking water for the population. Based on records from 2014 to 2020, a special edition of the Communication Series was published: "Environmental quality of drinking water sources of sanitation service companies in Chile. 2014-2020 period." The goal of this work was to move towards decision-making by the public body (i.e., Ministry of the Environment, Superintendence of Sanitary Services) that will stop the degradation of ecosystems by human activity and the pressure of climate change. RL4 researchers also produced the policy briefs "Use of the water footprint for a more sustainable management of water resources," "Water management in the framework of water security: A governance problem," and "Rainwater harvesting: encouraging diversification of the water matrix" to promote dialogue between scientific evidence and the generation of public policies by decision makers. In the case of the issue of "Rainwater harvesting," Gladys Vidal is working with a research group from the University of Pernambuco, as this Brazilian Institution is very strong on these issues.

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RL4 Research topics

The main forces driving this line of research, to connect "water and environment" and technology are: i) Circular economy: from recovery to reuse, ii) Technologies: wastewater treatment by conventional and non-conventional technologies and advanced membrane process for water treatment/reclamation, iii) Technology and nanotechnology for mining and agriculture, and iv) Sustainable management of the rhizosphere for soil-water remediation.

I) Circular economy: from recovery to reuse

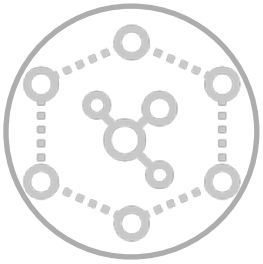
Within the framework of the circular economy, RL4 is working on optimizing the recovery of organic matter from wastewater to recover biogas and improve the energy balance of wastewater treatment plants (WWTPs), thereby converting them into power-generating plants (Barboza, 2022). In addition, Da Silva *et al.* (2022) developed a model to predict methane production from any type of waste. Meanwhile, wastewater reuse is an important strategy for confronting water scarcity. However, the removal of organic micropollutants remains a significant challenge for reuse technologies, and the importance of identifying and optimizing the operational conditions necessary to provide efficient, safe, and consistent removal, both in terms of the presence of the above-mentioned contaminants and challenges such as antibiotic-resistant microorganisms, is emphasized (Riquelme *et al.*, 2022). Moreover, this practice may contribute to the dissemination of antibiotic resistance genes to the environment, a matter of global concern. Leiva *et al.* (2022) studied the reuse of treated wastewater in agriculture under the perspective of the risks associated with ARG dissemination. Finally, Monsalvez *et al.* (2022) evaluated the performance of constructed wetlands (CW) used to reduce antibiotic resistance genes (ARGs) during sewage treatment.

II) Technologies: wastewater treatment by conventional and non-conventional technologies and advanced membrane process for water treatment/reclamation

Conventional wastewater treatment for the minimization of sludge production during wastewater treatment is essential because sludge management is one of the most critical issues in WWTP operation, accounting for 25% to 65% of overall operating costs. In Chile, as in many Latin American countries, about 80% of cities are smaller than 24,000 population equivalents, and consequently the number of WWTPs without anaerobic sludge digesters is significant. Therefore, other technologies for in situ reduction of sludge that could be applied in small WWTPs are gaining attention. Ozonation technology that reduces sludge production is considered during the design of small WWTPs, which would significantly decrease overall wastewater treatment costs (Crutchik *et al.*, 2022). Meanwhile, the fluidized bed reactor has the highest treatment capacity for nitrogen removal. This conventional technology is the key that in the future will allow groundwater treatment systems to be implemented at full scale to remove nitrate from Chilean groundwater (Franchi *et al.*, 2022).

Non-conventional technologies: Green technologies or nature-based solutions (NBS) for wastewater treatment in rural communities. Two non-conventional technologies can be used for rural wastewater treatment. Constructed wetlands with different cultures can be useful for removing organic matter, and partially nutrients. The behavior of phosphorus uptake was higher for a polyculture planted with ornamentals (Carrillo *et al.*, 2022). Another alternative for rural wastewater treatment is the use of algal-bacterial consortia. This work also shows how algal-bacterial consortia can be a sanitation solution for small communities. High removal of ammoniacal nitrogen and organic matter without external aeration at 34 days of hydraulic retention time and the possibility of nutrient recovery in the microalgal biomass, among other results, were found.

Advanced membrane process for water treatment/reclamation: Over the last few years, research has been conducted on the development of forward osmosis as an alternative for high-quality water reclamation from wastewater of different origins. During reported period, a study was published on membrane concentration of sewage as a tool for resource recovery and sanitation improvement (Ortega-Bravo *et al.*, 2022).



III) Technology and nanotechnology for mining and agriculture

Nanotechnology for recovery of water for mining and agriculture and other applications. During this period, we have worked on the application of microbial-induced calcite precipitation (MICP) to increase sustainability of tailings deposits. PhD student Héctor Zúñiga was awarded with funding from ANID to do a research internship at Huelva University (Spain) to study the possibility of inducing calcite precipitation using microalgae. This study is working together with RL1 on the use of MICP for calcium removal from seawater, to facilitate its use in mineral processing operations. On the other hand, the use of nanobiotechnology by means of biogenic nanoparticles has shown great potential for environmental decontamination, as they do not generate environmental contaminants. Biogenic synthesis and production of metallic nanoparticles have been developed by our investigation group (FONDECYT 1191089) for different areas of research, such as their use in agriculture (ANID-FAPESP 2018/08194-2, Parada *et al.,* 2022; doctoral dissertation of D. Martínez; FONDECYT Postdoctorado 3200963, FONDECYT Postdoctorado 3180279), water treatment (Hermosilla *et al.*, 2022; doctoral dissertation of W. Herrera), medicine (Cisternas *et al.*, 2022), enhancing biological processes (Hoffmann *et al.,* 2022), and obtaining value-added products (FONDECYT Postdoctorado 3190922; doctoral dissertation of J. Vera). Therefore, the production and application of biogenic nanoparticles could be considered a contribution to the development of new technologies to increase the productivity of our country.

Pesticides in the environment and mitigation by adsorption and biodegradation processes and their adaptation for industrial wastewater treatment

This work provides the basis for implementing a continuous treatment system using free and immobilized consortia of bacterial and fungi isolated from a biomixture of a biopurification system for treatment of wastewater containing pesticide mixtures (FONDECYT 1211738) capable of removing the pesticides efficiently, with a reduction of the half-life time (T1/2) of these compounds (doctoral dissertation of Marcela Levio and Barbara Leiva). With the aim of achieving better and faster pesticide degradation, we obtained biosurfactant-producing bacteria found in contaminated environments such as a biopurification system for pesticide treatment, which presented high biosurfactant production with great potential for environmental applications (FONDECYT 1211738; FONDECYT 3190918; undergraduate thesis of Cesar Llafquen, Diez *et al.*, 2022).

IV) Sustainable management of the rhizosphere for soil-water remediation, efficient water use, and agricultural production

In addition, research within RL4 has allowed several soil microorganisms with potential for use as inoculants under drought conditions to be obtained. These organisms have been isolated from diverse elevation belts in the Tarapacá Region (arid zone), central zone (Valparaíso Region), La Araucanía Region, and Antarctica (projects FONDECYT Regular 1210964, InES19-FRO19001, INACH RT_16-20). The isolations have allowed for a battery of strains that are also being used in the activities of CRHIAM and ANID FSEQ210002. Meanwhile, a pilot system has been established for the reuse of salinized water by plants inoculated with mycorrhizal fungi in hydroponic systems (FONDECYT Postdoctorate 3210588) and to corroborate the effect of positive stress at low saline concentrations in lettuce plants (Santander *et al.*, 2022). The results have demonstrated the ability of AM fungi to modify the metabolic profiles of colonized plants (Nahuelcura *et al.*, 2021; Tereucán *et al.,* 2022; Alarcón *et al.,* 2022; Fritz *et al.*, 2022), the use of microalgae extracts (Nostoc sp.) as biostimulants of lettuce plants (Silambarasan *et al.*, 2021), the degradation of organic contaminants by bacterial isolates (Silambarasan *et al.,* 2022a), the increase in aluminum tolerance by actinobacteria (Silambarasan *et al.*, 2022b), and the optimization of cadmium phytoextraction processes with inoculation of sorghum plants with actinobacteria (Silambarasan *et al.*, 2022c), and through international cooperation a review of the role of beneficial microorganisms in coffee cultivation was carried out (Urgiles *et al.*, 2021).

4.5 RL5 - Water governance, ecosystem services, and sustainability

Interdisciplinary work

Chile is undergoing a series of challenges resulting from the proposed constitutional change that was ultimately rejected. However, the discussion will continue in the coming years, and water regulations will be at its core. Amid this period of major socioecological transformations, CRHIAM researchers led by Dr. Jorge Rojas, together with colleagues from the University of Jena (Dr. Klaus Dorre) in Germany, edited a book entitled: Global Socioecological Transformations: Post-pandemic Society, Climate Change, Nature and Democracy (RIL edition in Spanish). This book was launched at the Latin American Sociology meeting in Mexico in August 2022. It represents an international effort to understand societal transformations and how Latin American societies are adapting to these challenges. The book included a chapter written by the current Chilean Minister of the Environment, Dr. Maisa Rojas (an expert on Climate Change) and a chapter on water and education by CRHIAM researcher Dr. Ricardo Barra.

Collaboration with international and national companies

In instances of international collaboration, Dr. Arumí is participating in two research projects related to the study of headwaters and their relationship with communities. Through the joint work of the CYTED Network on Water Planting and Harvesting (SYCA), Dr. Arumí participated in an international congress on this subject and generated collaboration networks with Drs. Sergio Martus and Jorge Jodar from the Instituto Geominero de España (IGME); with Dr. Jodar, an application was submitted to the regular FONDECYT 2023 contest on the study of the role of snowmelt in groundwater recharge.

Contribution of scientific evidence to the country's public policies

Dr. Arumí has continuously participated in different instances of discussion on public policies related to water resources management in Chile. Since 2011 he has participated in the Water and Environment table, which is an authority created by the Association of Sanitary Companies (Andes). In 2021 he was elected director of the Association of Irrigation and Drainage Association (AGRYD), and he is an advisor to the board of directors of the Chilean chapter of the Latin American Association of Underground Hydrology. This year he became one of the founders of the group "Together for Water," which seeks to be a technical authority for discussion of public policies on water resources.

RL research topics

I) Desalination

A paper published by the PhD student Garcia-Bartolomei *et al.* (2022), who was supervised by R. Barra, discussed the issue of desalination plant placement along the Chilean coast in the north of the country, concluding that there are not many spaces suitable for installing desalination plants and that several factors must be taken in to account to decide where to set up a new desalination development, despite the length of the country's coast. The study concludes that less than 4% of the coastal area in the northern and north-central parts of the country may be suitable for installing desalination plants, considering a series of criteria such as distance to potential users, highways, protected areas, etc.

II) Water governance and ecosystem services

The development of integrated river basin management (IRBM) is necessary to achieve water security. An analysis of different governance approaches under the "good enough" water governance and metagovernance approaches was conducted by CRHIAM researchers Ricardo Figueroa and Roberto Ponce (Julio *et al.*, 2021; Julio and Figueroa, 2022; Julio *et al.*, 2022). This analysis involved hierarchical, market, and network governance models. The main conclusion is that a strong combination of the three governance models could be the best approach to move towards achieving water security and conservation of ecosystem services, encompassing the OECD water governance dimensions.

In addition, a comparative analysis of water resources management in Mexico, Chile, and Brazil, was conducted, addressing the issue of Sustainable Development Goal 6.5.1 regarding the degree of implementation of integrated water resources management and its correlation to the OECD principles on water governance. These three countries present poor performance in areas related to gender, finance, and information for decision making (Tinoco *et al.*, 2022).

A water governance analysis based on the wetlands in the metropolitan Concepcion Area in southern Chile were performed by Quevedo *et al.* (2022); a polycentric, more participative model is envisaged for a better water management.

A total of 116 indicators were used to assess the current status and trends of biodiversity and ecosystem services provided by the Biobío River basin (one of the largest Mediterranean rivers in South America) by identifying the direct drivers of change that alter the functions and capacity to provide ES in the future, identifying 16 services with a high level of impairment. The results indicate that land-use change, and overexploitation of raw materials are the most important drivers of change in the transformation of aquatic ecosystems in this area. This assessment of aquatic ecosystem trends and the analysis of environmental conflicts related to competing uses will allow decision-makers to prioritize certain management processes at the river basin scale and highlights the importance of ecosystem and biodiversity conservation for human well-being (Díaz *et al.*, 2022a).

In a study on pollution and biodiversity protection, the presence of microplastics was analyzed in this same basin, as they are considered among the most serious environmental pollutants worldwide, potentially affecting biological diversity, ecosystem functioning, and human health. Microplastics were found to be present throughout the basin, with a significantly higher presence in the lower basin, related to the size of the human population (Correa-Araneda *et al.*, 2022).

III) Water and socioenvironmental conflicts

The relationships between forestry extractivism and water/cultural sustainability are problematic, particularly in the current scenario of growing socioenvironmental and territorial conflicts associated with both forestry plantations and pulp mills. Along with the megadrought, pines and eucalyptus have a direct impact on rural drinking water systems, as these systems' sources of groundwater are being exhausted by forestry monocultures that cover large geographical areas. This mainly affects to the rural population, particularly farmers and the Mapuche people. The large-scale extraction of water by pines and eucalyptus (what we call "water extractivism;" see Torres *et al.,* 2022) are aimed at producing timber and feeding the cellulose plants located in several regions of Chile. One of them is the so-called "MAPA" plant (for its Spanish acronym meaning "modernization and expansion of the old ARAUCO plant") located in the Arauco Province. The old plant produces around 700,000 tons of cellulose per year, while the MAPA plant is going to produce 2.1 million of tons of cellulose per year, tripling the demand for forestry monoculture for its operation. Therefore, growing water and territorial conflicts in the area inhabited by both Chilean and Mapuche people are expected, as is increased pressure on the port city of Coronel, already a so-called "sacrifice zone," from which the forestry production of MAPA will be exported to the global markets. It should be noted that the ARAUCO holding company, MAPA's owner, also controls the port of Coronel. We explore these relationships between forestry extractivism and the (re) production of a sacrifice zone in Cuevas *et al.* (2022).

IV) Economics

The effects of climate change are a source of uncertainty for businesses worldwide, with climate change causing significant and disruptive changes to the socioecological systems in which firms and organizations interact. Amid this backdrop, a team of researchers led by Roberto Ponce developed a holistic assessment of the intersection of climate change and organizational literature since the end of the 20th century (Díaz *et al.*, 2022b). An overview of the results indicated that this field is highly concentrated, with most of the productivity occurring in the last five years, with two regions, Europe and the USA, accounting for more than 65% of all published papers. The high concentration uncovered here could be explained by the fact that climate change is a relatively new field of study within the business, economics, and management spheres. It could also provide fertile ground for new research opportunities.

CRHIAM

CENTRO DE RECURSOS HÍDRICOS PARA LA AGRICULTURA Y LA MINERÍA

ANID/FONDAP/15130015

Annual **Report** 2022

5 What and how much we published during 2022?

5.1 Publications indexed by web of science (WoS)

1. Carrasco-Benavides, M., Ortega-Farías, S., M. Gil, P., Knopp, D., Morales-Salinas, L., Lagos, O., de la Fuente, D., López-Olivari, R. and Fuentes, S. 2021. Assessment of the vineyard water footprint by using ancillary data and EEFlux satellite images. Examples in the Chilean central zone. Science of the Total Environment, 811: 152452.

2. Luarte, T., Tucca, F., Nimptsch, J., Woelfl, S., Casas, G., Dachs, J., Chiang, G., Pozo, K., Barra, R. and Galbán-Malagón, C. 2022. Occurrence and air-water diffusive exchange legacy persistent organic pollutants in an oligotrophic north Patagonian lake. Environmental Research, 204: 112042.

3. Cabrera, F., Torres-Aravena, A., Pinto-Ibieta, F., Campos, J.L. and Jeison, D. 2022. On-Line Control of Feast/Famine Cycles to Improve PHB Accumulation during Cultivation of Mixed Microbial Cultures in Sequential Batch Reactors. International Journal of Environmental Research and Public Health, 18(3): 12611. **(Synergy between researchers from the same line of Research - RL4. Technology for water treatment and environmental remediation).**

4. Leiva, W., Piceros, E., Robles, P. and Jeldres, R. 2022. Impact of hydrodynamic conditions on the structure of clay-based tailings aggregates flocculated in freshwater and seawater. Minerals Engineering, 176: 107313.

5. Quezada, G, Mejía, A., Piceros, E., Robles, P., Nieto, S., Gálvez, E. and Jeldres, R. 2021. Describing the adsorption of sodium tripolyphosphate on kaolinite surfaces in a saline medium by molecular dynamics. Minerals Engineering, 175: 107280.

6. Santander, C., Vidal, G., Ruiz, A., Vidal, C. and Cornejo, P. 2022. Salinity Eustress Increases the Biosynthesis and Accumulation of Phenolic Compounds That Improve the Functional and Antioxidant Quality of Red Lettuce. Agronomy, 12(3): 598. **(Synergy between researchers from the same line of Research - RL4. Technology for water treatment and environmental remediation).**

7. Rama, F., Busico, G., Arumi, J.L., Kazakis, N., Colombani, N., Marfella, L., Hirata, R., Kruse, E., Sweeney, P. and Mastrocicco, M. 2022. Assessment of intrinsic aquifer vulnerability at continental scale through a critical application of the drastic framework: The case of South America. Science of the Total Environment, 823: 153748.

8. Julio, N., Figueroa, R. and Ponce Oliva, R.D. 2022. Advancing toward water security: addressing governance failures through a metagovernance of modes approach. Sustainability Science, *in press.* **(Synergy between researchers from the same line of Research - RL5. Water governance, ecosystem services and sustainability).**

9. Alarcón, S., Tereucán, G., Cornejo, P., Contreras, B. and Ruiz, A. 2022. Metabolic and antioxidant effects of inoculation with arbuscular mycorrhizal fungi in crops of flesh-coloured Solanum tuberosum treated with fungicides. Journal of The Science of Food and Agriculture, 102(6): 2270-2280.

10. Fritz, V., Tereucán, G., Santander, C., Contreras, B., Cornejo, P., Ferreira, P.A.A. and Ruiz, A. 2022. Effect of Inoculation with Arbuscular Mycorrhizal Fungi and Fungicide Application on the Secondary Metabolism of Solanum tuberosum Leaves. Plants, 1(3): 278.

11. Santana, L., Rivera, D. and Forcael, E. 2022. Force Measurement with a Strain Gauge Subjected to Pure Bending in the Fluid–Wall Interaction of Open Water Channels. Applied Sciences, 12(3): 1744.

12. Nieto, S., Toro, N., Robles, P., Gálvez, E., Gallegos, S. and Jeldres, R.I. 2022. Flocculation of Clay-Based Tailings: Differences of Kaolin and Sodium Montmorillonite in Salt Medium. Materials, 15(3): 1156.

13. Soto, C., Toro, N., Gallegos, S., Gálvez, E., Robledo-Cabrera, A., Jeldres, R.I., Jeldres, M., Robles, P. and López-Valdivieso, A. 2022. Study of Molybdenite Floatability: Effect of Clays and Seawater. Materials, 15(3): 1136.

14. Jeldres, M., Toro, N., Gallegos, S., Robles, P., Salazar, I., Fawell, P.D. and Jeldres, R.I. 2022. Reducing Magnesium within Seawater Used in Mineral Processing to Improve Water Recovery and Rheological Properties When Dewatering Clay-Based Tailings. Polymers, 14(2): 339.

15. Crutchik, D., Franchi, O., Jeison, D., Vidal, G., Pinto, A., Pedrouso, A. and Campos, J.L. 2022. Techno-economic evaluation of ozone application to reduce sludge production in small urban WWTPs. Sustainability, 14(5): 2480. **(Synergy between researchers from the same line of Research - RL4. Technology for water treatment and environmental remediation).**

16. Calderón, C., Levio-Raimán, M. and Diez, M.C. 2021. Cadmium removal from giant squid (Dosidicus gigas) hydrolyzed in fixed-bed columns packed with iminodiacetic resin: tools for scaling-up the process. International Journal of Environmental Research and Public Health,19: 442.

17. Chamorro, S., Hernández, L., Saéz, K. Gómez, G. and Vidal, G. 2022. Effects of black liquor shocks on stability of activated sludge treatment of kraft pulp mill effluent: Morphological alteration in *Daphnia magna* and mutagenicity and genotoxicity response in *Salmonella typhimurium.* Sustainability,*14: 3869.*

18. Ortega-Bravo, J.C., Pavez, J., Hidalgo, V., Reyes-Caniupán, I., Torres-Aravena, A. and Jeison, D. 2022. Biogas Production from Concentrated Municipal Sewage by Forward Osmosis, Micro and Ultrafiltration. Sustainability, 14(5): 2629.

19. Sadino-Riquelme, M.C., Rivas, J., Jeison, D., Donoso-Bravo, A. and Hayes, R. 2022. Investigating a Stirred Bioreactor: Impact of Evolving Fermentation Broth Pseudoplastic Rheology on Mixing Mechanisms. Fermentation, 102: 2480.

20. Pérez, K., Toro, N., Jeldres, M., Gálvez, E., Robles, P., Alvarado, O., Toledo, P. and Jeldres, R. 2022. Estimating the Shear Resistance of Flocculated Kaolin Aggregates: Effect of Flocculation Time, Flocculant Dose, and Water Quality. Polymers, 14(7): 1381. **(Synergy between researchers from the same line of Research - RL2. New water sources for agriculture, mining and communities).**

21. Tariq, A., Chakhaia, T., Dahal, S., Ewing, A., Hua, X., Ofori, S.K., Prince, O., Salindri, A., Adeniyi, A.E., Banda, J.M., Skums, P., Luo, R., Lara-Díaz, L.Y., Bürger, R., Fung, I., Shim, E., Kirpich, A., Srivastava, A. and Chowell, G. 2022. An investigation of spatial-temporal patterns and predictions of the coronavirus 2019 pandemic in Colombia, 2020-2021. PloS Neglected Tropical Diseases,16(3): e0010228.

22. Correa-Araneda, F., Pérez, J., Tonin, A., Esse, C., Boyero, L., Díaz, M.E., Figueroa, R., Santander-Massa, R., Cornejo, A., Link, O., Jorquera, E. and Urbina, M. 2022. Microplastic concentration, distribution and dynamics along one of the largest Mediterranean-climate rivers: A whole watershed approach. Environmental Research, 209: 112808.

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5.2 Publications in some media

In 2022, CRHIAM appeared in 164 appearances in different media. These included notes, interviews, opinion columns, interviews, among others, in which different researchers from the center participated. Table 8 below highlights some of these publications.

Table 8. 2022 publications in some media

Title	Publication Type /Media	Author or interviewee	Date
1. Effective footprint	Note / Induambiente Magazine	Vanessa Novoa, Yenifer González, Gloria Gómez, José Luis Arumí, Octavio Rojas and Gladys Vidal	27-12-2021
2. Desalination, a satellite and 19 other ideas due to drought step on the accelerator after government investment	Note / Biobío Chile	Leopoldo Gutiérrez	04-01-2022
3. Interdisciplinary research of excellence in water resources at the service of the country	Reportage / El Mercurio	Pedro Toledo, María Cristina Diez and Diego Rivera	23-01-2022
4. Scientific dissemination is key to educate about water	Note / El Mercurio	José Luis Arumí	23-01-2022
5. Governance and management of water within the framework of water security	Note / El Mercurio	Gladys Vidal	23-01-2022
6. Universidad de Concepción: Effective responses to sustainability challenges	Note / El Mercurio	CRHIAM	14-06-2022
7. Research of excellence and projects with an impact on the territory	Note / El Mercurio	Leopoldo Gutiérrez and Roberto Urrutia	28-06-2022
8. CRHIAM and Essbio create an alliance to work for water from the territories	Note / El Mercurio	CRHIAM	12-07-2022
9. CRHIAM prepares the 5th e-learning version of the Diploma on Water Resources for Sustainable Development	Note / El Mercurio	CRHIAM	09-08-2022

Table 8 (cont.). 2022 publications in some media

Title	Publication Type /Media	Author or interviewee	Date
10. CRHIAM: connecting research in water resources with society	Note / El Mercurio	CRHIAM	23-08-2022
11. Beneficial fungi	Note / Induambiente Magazine	Pablo Cornejo, Christian Santander and Gladys Vidal	30-08-2022
12. Alerts in the Water	Note / Induambiente Magazine	CRHIAM	04-11-2022

5.3 Books and Books Chapters

Books

1. Holzapfel, E., Orrego, X., Jara, J., Salgado, L. and Souto, C. Diciembre 2021. Manual Riego y Drenaje en frutales. Universidad de Concepción Editorial/Concepción/Chile. ISBN 978-956-227-502-6. 61 pages.

2. Vidal, G., Neumann, P. and Hospido, A. 2022. Análisis de ciclo de vida: Fundamentos y aplicaciones para la gestión sustentable de los recursos hídricos. Universidad de Concepción Editorial/ Concepción/Chile. ISBN 978-956-227-481-4. 130 pages.

3. Rojas, J. and Dorre, K. 2022. Transformaciones Socioecológicas Globales. Sociedad pospandemia, cambio climático, naturaleza y democracia. RIL Editors/Santiago/Chile. ISBN 978-956-01-0908-8. 434 pages.

4. Ortega, M.J., Campos, J.L. and Vidal, G. 2022. Evaluación del metabolismo microbiano para el monitoreo y la optimización de sistemas biológicos de tratamiento de efluentes industriales y aguas servidas. Universidad de Concepción Editorial/Concepción/Chile. ISBN 978-956-227-508-8. 49 pages.

5. Videla, S. 2022. En búsqueda del agua ancestral en el norte semiárido y árido de Chile. Universidad de Concepción Editorial/Concepción/Chile. ISBN 978-956-227-533-0. 154 pages

6. Centro de Recursos Hídricos para la Agricultura y la Minería (CRHIAM). 2022. Relatos del Agua. Universidad de Concepción Editorial/Concepción/Chile. ISBN 978-956-227-531-6. 81 pages.

Book Chapters

1. Casas, Y. 2022. Historia y metodología del análisis de ciclo de vida. In: Análisis de ciclo de vida: Fundamentos y aplicaciones para la gestión sustentable de los recursos hídricos. Universidad de Concepción Editorial/Concepción/Chile. ISBN 978-956-227-481-4. 13-40.

2. Riquelme, C. and Neumann, P. 2022. Indicadores de sustentabilidad y vinculación del análisis de ciclo de vida con herramientas de análisis y gestión ambiental. In: Análisis de ciclo de vida: Fundamentos y aplicaciones para la gestión sustentable de los recursos hídricos. Universidad de Concepción Editorial/Concepción/Chile. ISBN 978-956-227-481-4. 41-66.

3. Neumann, P. 2022. Aplicación del análisis de ciclo de vida a los sistemas de tratamiento de aguas servidas. In: Análisis de ciclo de vida: Fundamentos y aplicaciones para la gestión sustentable de los recursos hídricos. Universidad de Concepción Editorial/Concepción/Chile. ISBN 978-956-227-481-4. 67-94.

4. Casas, Y. and Vidal, G. 2022. Huella del agua. In: Análisis de ciclo de vida: Fundamentos y aplicaciones para la gestión sustentable de los recursos hídricos. Universidad de Concepción Editorial/Concepción/Chile. ISBN 978-956-227-481-4. 95-133.

5. Contreras, J., Leiva, A.M., González, Y. and Vidal, G. 2022. What is Latin America doing regarding the research and teaching of Nature-based solutions (NbS) to boost environmental education?. In: Enhancing environmental education through nature-based solutions. Springer Nature/Switzerland. ISBN 978-3-030-91843-9. 133-151.

6. Vidal, G., Neumann, P. and Gómez, G. 2022. Towards a circular economy of sewage sludge anaerobic digestion: relevance of pre-treatment processes and micropollutants presence for sustainable management. In: Anaerobic Biodigesters for Human Waste Treatment. Springer Nature Singapore Pte Ltd/Singapore. ISBN 978-981-19-4920-3. 217-232.

7. Concha, F. and Bürger, R. 2022. Sedimentation. In: Particle Separation Techniques: Fundamentals, Instrumentation, and Selected Applications. Elsevier/Amsterdam/The Netherlands. ISBN 978-032-385-486-3. 155-177.

8. González, Y., Salgado, P., Gómez, G. and Vidal, G. 2022. Advanced sewage disinfection technologies eco-friendly with the environment and public health. In: Sustainable Management of Environmental Contaminants, Environmental Contamination Remediation and Management. Springer Nature/Singapore. ISBN 978-3-031-08445-4. 51-69.

9. Pannunzio, A., Holzapfel, E.A. and Texeira, P. 2022. Assessment of the Recession Phase in a Drip Irrigated Blueberry (Hybrid Cross of Vaccinium sp.) Crop under Different Irrigation Design Criteria and Irrigation Scheduling in Concordia, Entre Ríos, Argentina. In: Current Topics in Agricultural Sciences Vol. 6. Book Publisher International/Londres/Reino Unido. ISBN 978-93-5547-515-2. 90-101.

10. Leiva, A.M., Piña, B. and Vidal, G. 2022. Risks associated with the circular economy: Treated sewage reuse in agriculture. In: Circular Economy and Sustainability, Volume 2: Environmental Engineering. Elsevier/Amsterdam/Netherlands. ISBN 978-0-12-821664-4. 37-48.

11. López, D., González, T., Gómez, G., Miranda, J.P., Contreras, J. and Vidal, G. 2022. Searching for sustainability in organic matter and nitrogen removal by integrating constructed wetlands and microbial fuel cells. In: Circular Economy and Sustainability, Volume 2: Environmental Engineering. Elsevier/Amsterdam/Netherlands. ISBN 978-0-12-821664-4. 283-296.

12. Holzapfel, E., Souto, C. and Orrego, X. 2022. Métodos de riego en frutales. In: Manual Riego y Drenaje en frutales. Editorial Universidad de Concepción/Concepción/Chile. ISBN 978-956-227-502-6. 23-44.

5.4 Providing Evidence and Knowledge for Public Policies: CRHIAM Communication Series and Policy Briefs

CRHIAM Communication Series

1. Toledo, P., Rozas, R., Quezada, G., Saavedra, J. and Gutiérrez, L. 2022. ¿Sal o no sal? Esa es la cuestión en procesos con agua salada. Serie Comunicacional CRHIAM, Water Research Center for Agriculture and Mining, ISSN 0718-6460 (printed version), ISSN 0719-3009 (online version), number 29, 37p.

2. Carrillo, V., Gómez, G., Fuentes, B., Lagos, O. and Vidal, G. 2022. El fósforo como nutriente: perspectivas globales, ambientales y su aplicación en la agricultura. Serie Comunicacional CRHIAM, Water Research Center for Agriculture and Mining, ISSN 0718-6460 (printed version), ISSN 0719-3009 (online version), number 30, 37p.

3. Vega, D., Gutiérrez, L., Urrutia, R. and Álvarez, D. 2022. La minería submarina y su potencial impacto. Serie Comunicacional CRHIAM, Water Research Center for Agriculture and Mining, ISSN 0718-6460 (printed version), ISSN 0719-3009 (online version), number 31, 29p.

4. Castillo, R., Bascur, B., Iglesias, K., Rivera, D., Alvez, A. and Torres, R. 2022. Disputas por el agua: actores e instituciones del contexto urbano y rural. Serie Comunicacional CRHIAM, Water Research Center for Agriculture and Mining, ISSN 0718-6460 (printed version), ISSN 0719-3009 (online version), number 32, 45p.

5. Concha, F., Vergara, M. and Toledo, P. 2022. Minería 4.0. Serie Comunicacional CRHIAM, Water Research Center for Agriculture and Mining, ISSN 0718-6460 (printed version), ISSN 0719-3009 (online version), number 33, 40p.

6. Ramírez, A., Gutiérrez, L. and Arumí, J.L. 2022. Calidad del agua y su uso en la minería. Serie Comunicacional CRHIAM, Water Research Center for Agriculture and Mining, ISSN 0718-6460 (printed version), ISSN 0719-3009 (online version), number 34, 32p.

7. Urrea, P., Oyarzún, R., Arumí, J.L. and Gutiérrez, L. 2022. Uso de herramientas isotópicas para estudios de problemas hidrológico-ambientales. Serie Comunicacional CRHIAM, Water Research Center for Agriculture and Mining, ISSN 0718-6460 (printed version), ISSN 0719-3009 (online version), number 35, 40p.

8. Pulgar, F., Jeldres, R., Concha, F. and Toledo, P. 2022. Uso de agua de mar en minería. Avances en el espesamiento de relaves ricos en arcillas. Serie Comunicacional CRHIAM, Water Research Center for Agriculture and Mining, ISSN 0718-6460 (printed version), ISSN 0719-3009 (online version), number 36, 33p.

9. Pérez, K., Jeldres, R., Toledo, P. and Gutiérrez, L. 2022. Calidad del agua recirculada en operaciones mineras. Mejoramiento mediante microesferas de vidrio químicamente funcionalizadas. Serie Comunicacional CRHIAM, Water Research Center for Agriculture and Mining, ISSN 0718-6460 (printed version), ISSN 0719-3009 (online version), number 37, 25p.

10. Toledo, P., Rozas, R., Yepsen, R. and Gutiérrez, L. 2022. Corre Litio que te pilla el Sodio. Serie Comunicacional CRHIAM, Water Research Center for Agriculture and Mining, ISSN 0718-6460 (printed version), ISSN 0719-3009 (online version), number 38, 19p.

11. Arriagada, L., Rivera, D., Ponce, R. and Munizaga, J. 2022. Vulnerabilidad de cuencas: Estresores y desafíos. Serie Comunicacional CRHIAM, Water Research Center for Agriculture and Mining, ISSN 0718-6460 (printed version), ISSN 0719-3009 (online version), number 39, 28p.

12. Crouchett, F., Arango, J., Bürger, R. and Jeison, D. 2022. Modelación matemática de sistemas biológicos: microalgas y bacterias para el tratamiento de aguas residuales. Serie Comunicacional CRHIAM, Water Research Center for Agriculture and Mining, ISSN 0718-6460 (printed version), ISSN 0719-3009 (online version), number 40, 26p.

13. Centro de Recursos Hídricos para la Agricultura y la Minería. 2022. Calidad ambiental de fuentes de agua potable de empresas de servicios sanitarios en Chile. Periodo 2014-2020. Serie Comunicacional CRHIAM, Water Research Center for Agriculture and Mining, ISSN 0718-6460 (printed version), ISSN 0719-3009 (online version), Special Edition, 83p.

14. Toledo, P., Alvarado, O., Rozas, R., Quezada, G. and Gutiérrez, L. 2022. Litio ¿Recurso estratégico? Para saber y contar. Serie Comunicacional CRHIAM, Water Research Center for Agriculture and Mining, ISSN 0718-6460 (printed version), ISSN 0719-3009 (online version), number 41, 37p.

15. Casas, Y., González, Y., Gómez, G., Holzapfel, E., Arroyo, N. and Vidal, G. 2022. Sustentabilidad de los sistemas de tratamiento de aguas servidas. Una mirada desde el análisis de ciclo de vida. Serie Comunicacional CRHIAM, Water Research Center for Agriculture and Mining, ISSN 0718-6460 (printed version), ISSN 0719-3009 (online version), number 42, 38p.

16. Martínez, R., Abreu, N., Lagos, O. and Barra, R. 2022. Modelación hidrológica para enfrentar los cambios globales. Serie Comunicacional CRHIAM, Water Research Center for Agriculture and Mining, ISSN 0718-6460 (printed version), ISSN 0719-3009 (online version), number 43, 31p.

17. Castillo, R., Barriga, F., Fernández, L., Gómez, G., Ortega, M.J., Alvez, A. and Vidal, G. 2022. Estudio comparado de la regulación de cosecha de aguas lluvias. Serie Comunicacional CRHIAM, Water Research Center for Agriculture and Mining, ISSN 0718-6460 (printed version), ISSN 0719-3009 (online version), number 44, 33p.

Policy Briefs

1. Arumí, J.L. and Urrutia, R. 2022. Construcción de embalses para enfrentar la escasez hídrica. Policy Brief CRHIAM, Water Research Center for Agriculture and Mining, ISSN 2735-7929 (printed version), ISSN 2735-7910 (online version), number 1, 6p.

2. Neumann, P. and Vidal, G. 2022. Uso de la huella del agua para una gestión más sustentable de los recursos hídricos. Policy Brief CRHIAM, Water Research Center for Agriculture and Mining, ISSN 2735-7929 (printed version), ISSN 2735-7910 (online version), number 2, 6p.

3. Rivero, S., Godoy, A. and Rivera, D. 2022. La transición hacia una alimentación saludable depende del incremento diferencial de la canasta de alimentos en el presupuesto familiar en los distintos quintiles. Policy Brief CRHIAM, Water Research Center for Agriculture and Mining, ISSN 2735-7929 (printed version), ISSN 2735-7910 (online version), number 3, 6p.

4. Figueroa, R., Vidal, G. and Ponce, R. 2022. Gestión del agua en el marco de la seguridad hídrica: un problema de gobernanza. Policy Brief CRHIAM, Water Research Center for Agriculture and Mining, ISSN 2735-7929 (printed version), ISSN 2735-7910 (online version), number 4, 5p.

5. Castillo, R., Barriga, F., Gómez, G., Ortega, M.J., Alvez, A. and Vidal, G. 2022. Cosecha de aguas lluvias: incentivando a diversificar la matriz hídrica. Policy Brief CRHIAM, Water Research Center for Agriculture and Mining, ISSN 2735-7929 (printed version), ISSN 2735-7910 (online version), number 5, 6p.

6. Toledo, P. and Gutiérrez, L. 2022. Recomendaciones para el uso sustentable del agua en la minería. Centro de Recursos Hídricos para la Agricultura y la Minería ISSN 2735-7929, Policy Brief CRHIAM, Water Research Center for Agriculture and Mining, ISSN 2735-7929 (printed version), ISSN 2735-7910 (online version), number 6, 5p.

CRHIAM

CENTRO DE RECURSOS HÍDRICOS PARA LA AGRICULTURA Y LA MINERÍA

ANID/FONDAP/15130015

Annual **Report** 2022

6 In 2022: We transfer our scientific knowledge to the community

6.1 CRHIAM Talks Cycle

The format of the talks consists of a presenter speaking on a topic that he or she is working on, allowing a look at work carried out in conjunction with other members of his or her cluster and other CRHIAM teams. It also offers a space for broad discussion that promotes an exchange of ideas between the presenter and the audience. From April to December, the CRHIAM Talks Cycle was held for the fourth consecutive year; it was broadcast live on Facebook. Thus, the talks could be seen in real time in different cities of the country and recordings were published on the center's social networks. This year included topics such as water in constituent process, mineral flotation with sea water, and life cycle thinking to make decisions, among others. Table 9 presents each of the topics addressed in the online 2022 CRHIAM Talks Cycle.

Table 9. 2022 CRHIAM Talks Cycle

Presenter	Presentation Title	Date
Rodrigo Castillo	Regulation and management of water in the constituent process	April 7th
Dr. Marcela Salgado	Local water governance experiences	May 5th
Dr. Lien Rodríguez	Fossil pigments and environmental conditions in Laja lake	June 2nd
Dr. Jorge Saavedra	Experiments, artificial vision and simulation in mineral flotation with sea water	July 7th
Dr. Denisse Álvarez	Lacustrine sediments and their use as climate change filing cabinets and past environmental	August 4th
Dr. Pablo Pedreros	Thermal regime and ecosystems freshwater	September 1st
Dr. Yannay Casas	Importance of life cycle thinking in making decisions	October 6th
Dr. Lina Uribe	Tailings and their relationship with water resources	December 1st

Figure 9 shows all the researchers who presented in the 2022 Talks Cycle.

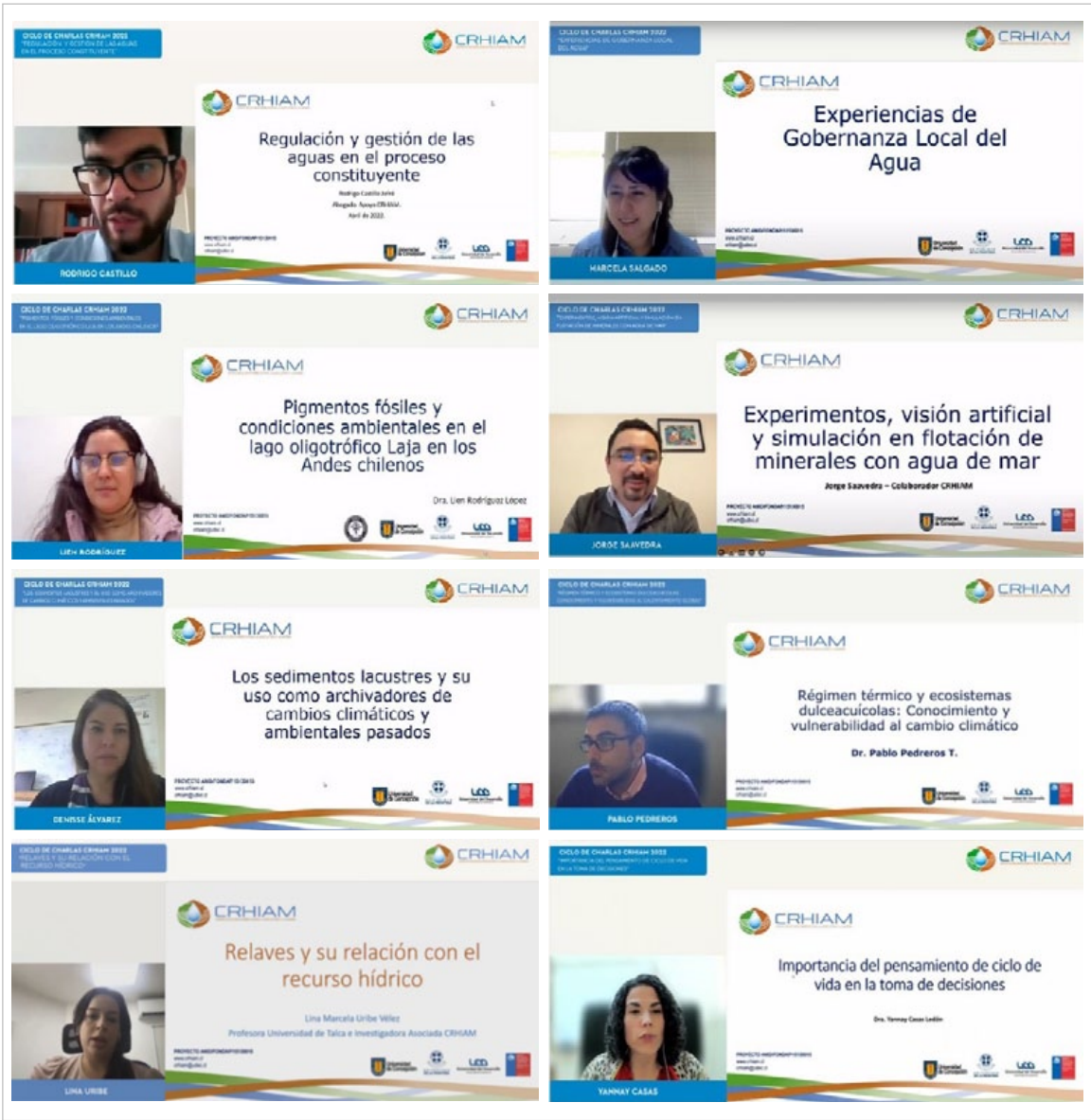


Figure 9. CRHIAM researchers presenting in the 2022 Talks Cycle.

6.2 CRHIAM International Activities

PRINCIPAL RESEARCHER TEACHED A SEMINAR ON GROUNDWATER TO STUDENTS OF THE UNIVERSIDAD AUTÓNOMA DE BAJA CALIFORNIA SUR

As a space to publicize water management in the country and the effects that climate change has had on its availability, Dr. José Luis Arumí, main researcher at CRHIAM, was invited to give the seminar "Groundwater and the mega drought in Chile. Gaps for future management in times of change" (Figure 10) to students of the Water Management and Sciences degree at the Autonomous University of Baja California Sur in Mexico.

The presentation addressed the availability of water in Chile and the differences that exist from north to south; the impact of climate change and mega drought, which has produced a greater dependence on groundwater systems; and the gaps that exist in their management.

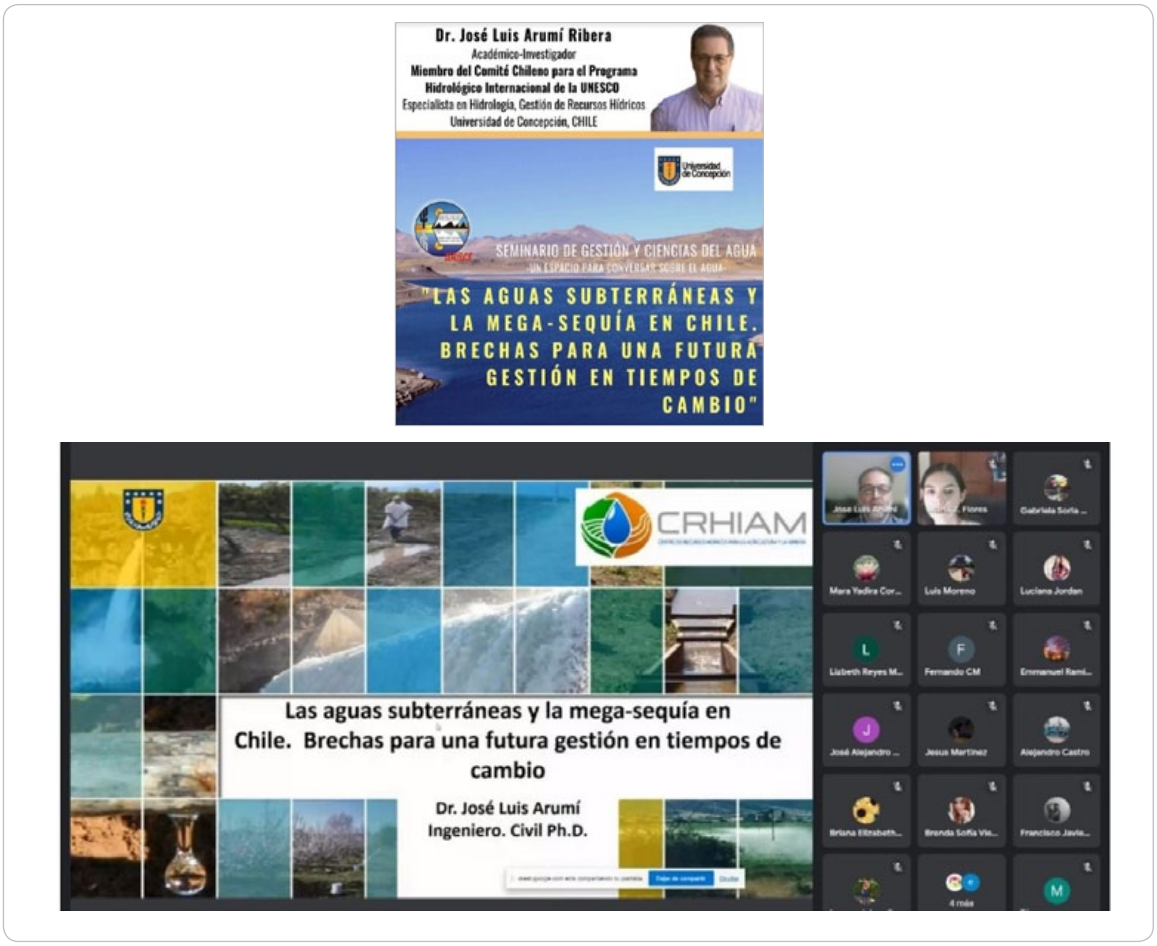


Figure 10. Dr. Arumí participation's in the Seminar on Water Management and Sciences.

UNIVERSITY OF CALGARY ACADEMIC TALK ON THE IMPORTANCE OF WATER BASIN MONITORING

"We cannot manage what we cannot measure", with these words began his presentation Dr. Kelly Munkittrick, academic from the Department of Biological Sciences of the University of Calgary, Canada, who gave the conference "Watershed monitoring and its value for water protection. Perspectives from Canada" (Figure 11).

The talk addressed the role of basin monitoring for decision-making, taking Canada's oil sands monitoring program as an example and the lessons they have learned in the last ten years, despite the fact that this initiative It has not had the expected results. Likewise, he linked this experience with the work carried out in CRHIAM, with a view to positioning the Center in the future.

Figure 11. Talk about the importance of monitoring water basin.

CRHIAM RESEARCHER CARRIED OUT RESEARCH STAY IN GERMANY

Dr. Roberto Rozas, CRHIAM associate researcher, carried out a research stay in Germany in March within the framework of the Fondecyt project "Molecular Simulation Study of Heterogeneous Nucleation and Growth in Metallic Systems and Alloys", an initiative that he leads (Figure 12).

On this occasion he met with academics Dr. Jürgen Horbach from the Institute for Theoretical Physics of the Heinrich-Heine University of Düsseldorf and with Dr. Peter Galenko, from the Otto Schott Institute of the Friedrich Schiller University of Jena.

Regarding the research work, Dr. Rozas explained that it focuses mainly on the study of metals and alloys, due to the large amount of experimental data that allows comparing the simulation results. "In particular, a better understanding of the crystal formation and growth phenomena that occur on the atomic scale is necessary. At this scale, molecular simulation is key since it allows direct observation of phenomena, but also access to some properties of liquid-crystal interfaces that cannot be determined experimentally", he pointed out.

The study also contemplates the development and implementation of new simulation methods for the estimation of these properties

Figure 12. Research stay of Dr. Rozas in Germany

ACADEMIC OF THE UNIVERSITY OF KOBLENZ-LANDAU DELIVERED A PRESENTATION ON THE ENVIRONMENTAL RISKS ASSOCIATED WITH THE USE OF PLASTIC

"Plast: dealing with environmental risks caused by plastic usage and consumption-An interdisciplinary contribution towards an ecological transformation", was the name of the open class for students of the Doctorate in Environmental Sciences of the UdeC, which was given by Dr. Katherine Muñoz, researcher from the University of Koblenz-Landau, in Germany (Figure 13).

This activity was carried out in a hybrid format and was organized by the Doctorate in Environmental Sciences, with the support of the Fondap CRHIAM Center, the Faculty of Environmental Sciences and the EULA Center.

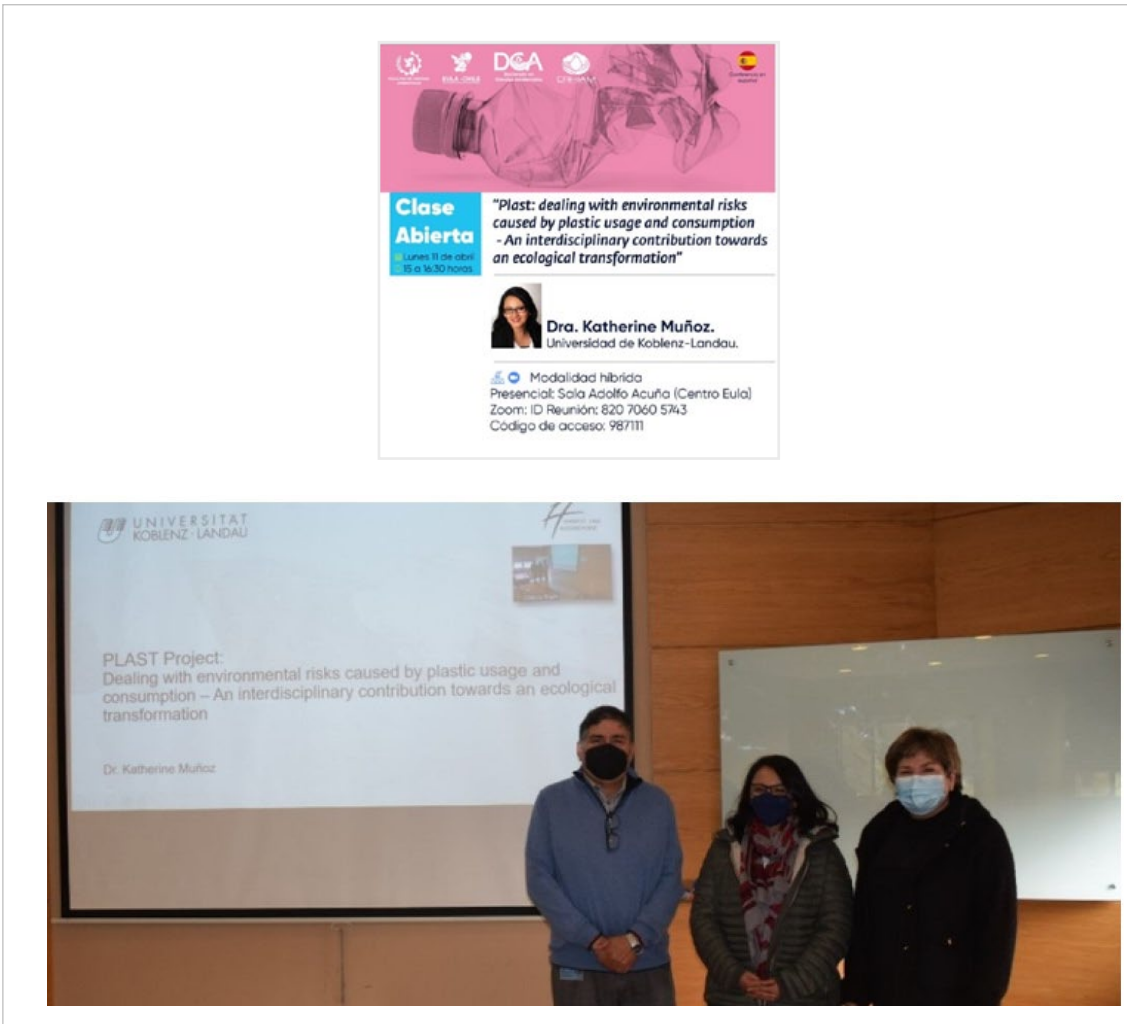


Figure 13. Open class on risks associated with the use and consumption of plastic.

ACADEMIC OF THE UNIVERSITY OF MÁLAGA GIVEN MASTER CLASS ON BLUE BIOTECHNOLOGY

Transforming marine resources into goods and services of medical interest is one of the objectives of blue biotechnology, a tool that is still in early development, but which already has promising applications. In this context, the master class "Polysaccharides from algae and fungi with immunomodulatory and anticancer properties was held. An opportunity for the nutraceutical industry", given by Dr. Roberto Abdala, professor at the University of Malaga. The academic was invited by Dr. Ricardo Figueroa, a researcher associated with CRHIAM, to report this class for all doctoral students in Environmental Sciences at the University of Concepción. The talk was held on May 13th in a hybrid format, in the Nonguén room of the Faculty of Environmental Sciences of the UdeC (Figure 14).

Dr. Abdala also visited the CRHIAM, where he was able to learn about the research work carried out by the Center. Regarding his stay in Chile, he pointed out that he is in our country thanks to an MEC project (Contest for Attracting Advanced Human Capital from Foreigners, Short Stay Modality), through which he has had the opportunity to show his research work on to blue biotechnology and its benefits.

Figure 14. Master class on blue biotechnology, by spanish professor.

CRHIAM MEMBER PARTICIPATED IN CONGRESS ON INTERNATIONAL LAW AND CONSTITUENT PROCESSES

"Symposium: International Law and Constitution Making" was the name of the event organized by the Rutgers Center for Transnational Law and the Diego Portales University Public Law Program, an instance in which Rodrigo Castillo, CRHIAM support attorney, participated. The activity was held on May 18th at Rutgers University, Newark, New Jersey, USA (Figure 15).

The event sought to reflect on the link between the constituent processes and international law. "In general, the focus of the symposium was focused on particular case studies, of which the constitutional process of Chile, currently underway, was the object of special attention by the participating academics, from various countries, such as Colombia, Spain, United States, England, Hungary, South Africa, Turkey and Chile", says Castillo.

On this occasion, he presented the work "The Regulation of Water as a Factor of Contradictory Influences for the Constitutional Process in Chile", which he carried out together with Dr. Amaya Alvez, a researcher associated with CRHIAM and the lawyer Kimberly Iglesias. The investigation "focused on identifying the different elements that from the international arena influence the regulation of the statute of waters in Chile, focusing on two key areas, such as International Human Rights Law, and the law related to the protection of investments", explained Castillo.

"The work presented is linked to a series of other documents prepared by CRHIAM on the consecration of the Human Right to Water, its fundamental statute and the follow-up of the constituent process and legislative debates in order to generate multiple reforms in water regulation. Its content tries to account for the various aspects of this matter, linking compliance with human rights standards, with the implications for productive activities and investments that water regulation has", he pointed out.

Figure 15. CRHIAM collaborator participated in an international symposium developed in the USA.

CRHIAM DIRECTOR EXHIBITED AT THE 6TH IWA-YWP MEXICO 2022

From May 23th to 27th, the 6th IWA-YWP Mexico 2022 conference was held, in which the director of CRHIAM, Dr. Gladys Vidal, participated with the presentation "Considerations for the management of treated wastewater for drinking water and agriculture reuse" (Figure 16).

She highlighted the importance of correctly reusing water, trying to guarantee its quality to avoid contamination of ecosystems and problems for the health of the population. The CRHIAM Director also pointed out that "it is key to have clear projections about the uses that reused water could have, since it is an interdisciplinary challenge that must connect multiple disciplines to be successful."

The 6th IWA-YWP Mexico 2022 is a forum in which young researchers and professionals who work on multiple and different issues related to water resources, present their work and have the opportunity to meet and interact with leading researchers, experts and government authorities from around the world.

Figure 16. Participation of the Director of CRHIAM in an international conference.

CRHIAM RESEARCHER PRESENTED ABOUT PRO-ENVIRONMENTAL BEHAVIOR OF COMPANIES AT INTERNATIONAL CONGRESS

"Moving from intention to action: Insights on firms' active pro-environmental behavior" is the research paper presented by CRHIAM associate researcher Dr. Roberto Ponce at the BALAS 2022 annual conference, an academic association focused exclusively on business and economy in Latin America and the Caribbean. The meeting took place in a hybrid way from June 9th to 13th in Lisbon, Portugal (Figure 17).

The study seeks to determine which are the characteristics of an organization that influence the probability of declaring environmental policies and to establish whether these pro-environmental policies or intentions are a good predictor of active pro-environmental behaviors. The results suggest that large export-oriented, family-owned and corporate group companies are more likely to incorporate environmental policies.

Likewise, the findings of this work would contribute to facilitating the design of public policies aimed at segments of the business ecosystem, thus promoting and stimulating pro-environmental actions more effectively.

Figure 17. CRHIAM researcher participated in international conference, developed in Portugal.

RESEARCHER FROM THE UNIVERSITY OF IDAHO PERFORMED A THREE MONTH STAY AT UDEC

Dr. Alan Kolok, director of the Idaho Water Resources Research Institute, made a stay from March to June 2022 at the Universidad de Concepción, thanks to a Fulbright scholarship that allowed him to strengthen ties with CRHIAM researchers, contribute to courses for the doctorate in Environmental Sciences at UdeC, and leading a workshop on ecotoxicology for postgraduate students, which was also part of the CRHIAM fall school (Figure 18).

Dr. Kolok is an internationally recognized scholar, having served as director and founder of the Nebraska Watershed Network at the University of Nebraska at Omaha, and as director of the Center for Environmental Health and Toxicology at the Nebraska Medical Center. from the University of Nebraska.

In addition, he has focused his career mainly on the study of ecotoxicology in water resources focused on the fate, transport and biological effects of pesticides and emerging pollutants. To this is added that it has numerous publications in scientific journals and digital media aimed at scientific dissemination.

Figure 18. Internationally recognized scholar developed a stay at Universidad de Concepción.

CRHIAM FALL SCHOOL WAS DELIVERED BY OUTSTANDING UNIVERSITY OF IDAHO RESEARCHER

From June 13th to 16th, the "Ecotoxicology Workshop" was held, a postgraduate course and part of CRHIAM's fall school, which was dictated by the director of the Idaho Water Resources Research Institute, Dr. Alan Kolok (Figure 19).

The course aimed to introduce the basic principles of toxicology, addressing the study of toxic chemicals and their fate, transport and impact, and the application of these concepts in an environmental context.

After the workshop, the students acquired the skills to examine and evaluate the possibility that any compound is toxic to the environment, how to make an initial evaluation of any chemical product and make inferences regarding its fate, transport and biological impact in the environment.

Figure 19. Postgraduate course taught by professor of Idaho Water Resources Research Institute.

CRHIAM DOCTORAL STUDENT PARTICIPATED IN THE 12TH MICROPOL & ECOHAZARD CONFERENCE

In Santiago de Compostela, the historic capital of the Galicia region, the 12th Micropol & Ecohazard Conference was held from June 6th to 10th, an initiative that is part of the series of conferences "Evaluation and control of hazardous substances in water" of the IWA, which are conceived as an international forum for the discussion of the state of the art in scientific development and technical solutions related to the emission, treatment and treatment of emerging pollutants (Figure 20).

Dr. (c) Ana María Leiva, doctoral student in Environmental Sciences at the Universidad de Concepción and CRHIAM doctoral student, presented two papers at the conference, an oral presentation entitled «Multivariate analysis for evaluating triclosan and ibuprofen removals in constructed wetlands», and the poster "Antibiotic resistance in wastewater treatment technologies and their implications on the reuse of treated wastewater".

Figure 20. CRHIAM doctoral student participated in international conference developed in Spain.

CRHIAM RESEARCHER MADE A BRIEF STAY IN SPAIN

In order to participate in a congress and conclude a scientific article, Dr. Mario Lillo, CRHIAM associate researcher, was in Spain from June 19th to July 1st, trip in which he also organized and gave the seminar "Consolidation of the data processing group for water resources".

His first stop was at the Data Mining and Simulation Laboratory (MIDAS), of the Polytechnic University of Madrid, where he was from June 19th to 29th. "The purpose of this stay was to develop the final part of a scientific article, and to have progress meetings, together with the thesis committee, with Doctoral student Meryeme Boumahdi, who will spend a stay at our university between the months of September and December 2022", he pointed.

In this same room, on July 21st, he held the seminar "Consolidation of the data processing group for water resources", in which he presented the progress of this group (Figure 21).

Figure 21. . CRHIAM Associated Research exposed about data processing for water resources.

CRHIAM RESEARCHER PRESENTED AT THE INTERNATIONAL CONGRESS ON HYPERBOLIC PROBLEMS

Dr. Raimund Bürger, associate researcher at CRHIAM, participated and spoke at the «XVIII International Conference on Hyperbolic Problems: Theory, Numerics, Applications (HYP2022)», held at the University of Malaga, Spain, and which took place from 20th to June 24th (Figure 22).

On this occasion, Dr. Bürger presented the paper «Degenerating triangular convection-diffusion systems modeling froth flotation», which deals with the modeling of flotation columns, especially considering the effect of foam drainage. "The model is of obvious interest for the description and improvement of water use in Chilean mining, but it also has non-standard properties, such as discontinuously defined flows and strongly degenerate diffusion, which make it interesting for mathematical research", explained the researcher CRHIAM.

This congress is held every two years in different parts of the world and brings together nearly 300 experts, mostly linked to mathematics. "We discuss advances in theory, numerical analysis, and applications of hyperbolic problems, which are broadly speaking mathematical models governed by propagation phenomena at finite speeds, such as wave propagation, vehicular traffic, sedimentation, flotation, among others", noted Dr. Bürger.

Figure 22. Dr. Raimund Bürger participated in International Conference carried out in Universidad de Málaga, Spain.

ERASMUS SCHOLARSHIP HOLDER CARRIED OUT A SIX-MONTH ACADEMIC STAY IN CHILE WITH THE SUPPORT OF CRHIAM

In April of this year, the Fondap CRHIAM Center received a Spanish student from the University of Valladolid, thanks to an agreement between this university and the University of Concepción. His stay was made possible thanks to an Erasmus exchange scholarship, which will allow him to spend six months in Latin America.

The scholarship recipient is Iván Moris, a student on the Master's Degree in Environmental Engineering at the University of Valladolid, who was awarded an Erasmus scholarship in 2020, however, the COVID-19 pandemic forced him to postpone his trip. This year he was finally able to finalize his exchange where he had the opportunity to carry out comparative work on the management and governance of wastewater between Chile and Spain.

"What I highlight most about the experience is the change that I am experiencing during these months. The possibility of traveling, getting to know different cultures, getting out of the routine and starting an experience during these months that I will probably remember all my life. I have to highlight the friendliness of the Chilean culture and people who have made me feel at home during these months", Moris said. In addition, the student has been able to tour Bolivia and Peru during his stay. "Beyond the academic purpose, I had always wanted to live in Latin America and learn about its culture. When the opportunity to carry out the exchange arose, I did not hesitate and applied", he assured (Figure 23a).

Regarding his research work to complete the master's degree, he highlights that he has been able to learn, from a more global perspective, how wastewater management works in Spain and Europe, and link it to the problems that Chile faces in this matter. He has been able to carry out this research thanks to the support of Dr. Gladys Vidal, CRHIAM Director who helped guide his postgraduate thesis called "Evaluation of the Spanish institutional framework for governance and management of wastewater sanitation in rural areas of Chile", which he defended and approved before an evaluation committee made up of: the director of the Master's program in Environmental Sciences of the Faculty of Environmental Sciences of the Universidad de Concepción, Dr. Mariela Yevenes, the professor of the same faculty, Dr. Pedro Arriagada, and the CRHIAM Director, Dr. Gladys Vidal (Figure 23b).

Figure 23. CRHIAM received and support the work of a Spanish student from the University of Valladolid. a) Spanish student getting to know South America and b) Master's thesis defense.

LUND UNIVERSITY RESEARCHER VISITED CRHIAM

Dr. Stefan Diehl, a prominent academic from the University of Lund, Sweden, made a two-week stay at the Universidad de Concepción with the support of CRHIAM. The purpose of his trip was to accompany the doctoral defense of Yolanda Vásquez, who studied the Doctorate in Applied Sciences program with a mention in Mathematical Engineering at the Universidad de Concepción, under the direction of Dr. Raimund Bürger, associate researcher at CRHIAM (Figure 24).

During his stay he also participated in the 5th CI2MA workshop "Mathematical modeling and simulation for bioprocesses, wastewater treatment and mineral processing", where he presented the talk "Froth flotation with drainage and sedimentation". "When you do research you always advance little by little, we review many results in the chemical engineering literature and try to capture the most relevant results with mathematical equations, in order to improve the simulations that we are carrying out", commented Dr. Diehl about his presentation at the workshop.

The academic has been linked to CRHIAM since the Center's inception, since part of his research work is linked to the study of water resources. Thanks to this, Lund University has established itself as an international partner of CRHIAM. "From my work area I see wastewater treatment and biomass sedimentation. Sewage and biomass treatment plants are used to clean the waters of nutrients. I also carry out studies on flotation in mineral processing, with wastewater treatment, to try to do mathematical modeling with advanced equations, to try to simulate and solve these problems that are related to water treatment," he explained.

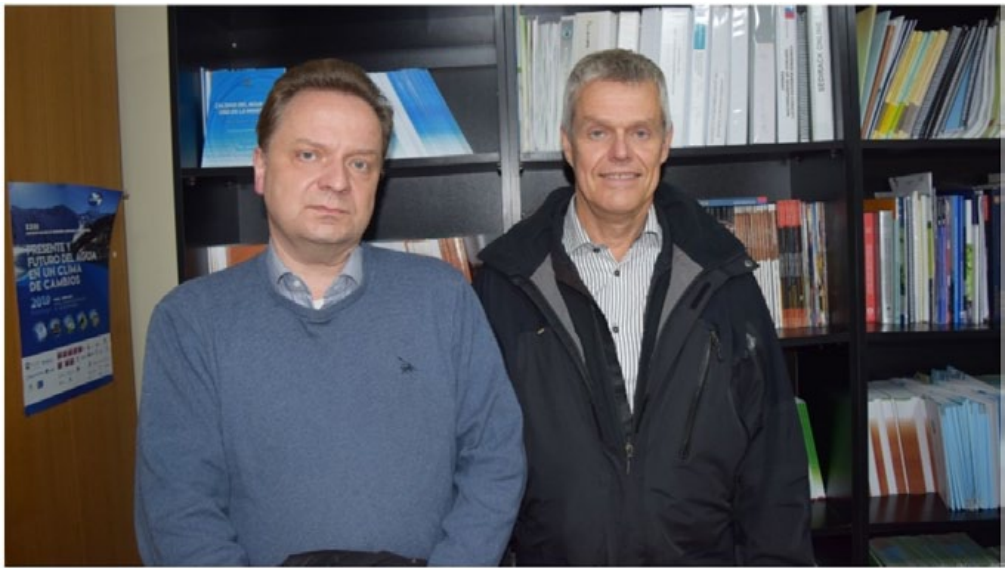


Figure 24. Dr. Stefan Diehl, a prominent academic from the University of Lund, Sweden visited the Universidad de Concepción supported by CRHIAM.

CRHIAM RESEARCHER PARTICIPATED IN THE INTERNATIONAL MEETING ON THE DEVELOPMENT AND APPLICATION OF ISOTOPIC TECHNIQUES TO OPTIMIZE THE USE OF WATER IN MINING AREAS

With the aim of testing and developing nuclear capacities and methodologies based on the use of isotopic hydrology tools, for the efficient evaluation and management of water resources in mining areas, the first meeting of the coordination research project (CRP F33026), an initiative promoted by the International Atomic Energy Agency (IAEA).

This meeting was attended by CRHIAM associate researcher Dr. Ricardo Oyarzún, who is a member of the Fondecyt 1210177 project "A coupled isotopic-geochemical assessment of hydrological dynamic in headwater andean basins in north-central Chile", in which they are co-researcher. Denisse Duhalde (academician of the Dept. of Mining Engineering, ULS), Dr. José Luis Arumí (principal researcher of CRHIAM) and Dr. Shelley MacDonell (CEAZA and U. Canterburry researcher).

"Although the call of the CRP was in 2020, due to Covid-19, the first meeting could only be held now (July 2022). This considered in a first part the presentation of the situation (case study) of each participating country, which covered an interesting range of situations and configurations. Subsequently, work was carried out in groups and in plenary sessions, addressing aspects related to the use of isotopic tools, analysis requirements, support possibilities between different countries, and availability of analytical capacity", explained Dr. Oyarzún. This was the only Chilean initiative selected to participate in this meeting, to which around 48 proposals were submitted, selecting a total of 17 from Brazil, Mexico, the Philippines, India, Pakistan, France, Italy, Zimbabwe, Poland, Ecuador, among others countries (Figure 25).

Figure 25. International Meeting was attended by CRHIAM Associate Researcher.

PERU ACADEMIC GIVEN A CONFERENCE ON WATER EDUCATION

The academic of the La Molina National Agrarian University, Rosa Miglio Toledo, presented the conference "Experience of implementation of constructed wetlands to support training at the child, youth and university level", which was given within the framework of the cycle of talks of the Doctorate in Environmental Sciences mention in Continental Aquatic Systems, from the University of Concepción (Figure 26). This activity was moderated by the director of CRHIAM, Dr. Gladys Vidal.

In this conference, the academic Rosa Miglio spoke about the importance of dissemination and linkage between communities and water, so that through education the value of water is recognized. She showed the work carried out within the framework of the Aiguatech program (Water Education and Technology Program for the child and adolescent population of Peru), which consisted of the installation of pilot units that contributed to the research, training, operation and maintenance generated under this technology.

The academic Rosa Miglio Toledo is an Agricultural Engineer, with a master's degree in the same subject and a doctorate in Engineering and Environmental Sciences. She is a Principal Professor at the La Molina National Agrarian University of Peru with 40 years of experience in teaching; She has been Dean of the Faculty of Agricultural Engineering, and head of the Department of Territorial Planning and Sustainable Development of the same Faculty. She carried out a project and a conference on the relevance of water education.

Figure 26. Conference given by academic of the La Molina National Agrarian University.

UNIVERSITY OF TORONTO ACADEMIC TALK ON THE EXPLOITATION OF RARE EARTH IN CHILE

To learn more about the exploitation of rare earths in the world and in our country, Dr. Gisele Azimi, an academic from the University of Toronto, gave the talk "Introduction to rare earth elements and results for their recovery from the Chilean ionic clays" (Figure 27), activity that was moderated by the principal investigator of CRHIAM, Dr. Leopoldo Gutiérrez.

"Chile is a copper-oriented country, however, it is necessary to address other issues associated with mineral processing, and this is one of them," said Dr. Leopoldo Gutiérrez, who stressed that "it is important to recover these elements strategic".

Dr. Azimi is an expert in the fields of electrochemistry, thermodynamics, hydrometallurgy, supercritical fluids, and materials design. The talk was aimed at undergraduate and graduate students of Civil Metallurgical Engineering, which mainly dealt with the issue of the exploitation of rare earths in Chile.

Figure 27. Talk given by academic Dr. Gisele Azimi of the University of Toronto.

CRHIAM RESEARCHER PRESENTED BOOK ON SOCIO-ECOLOGICAL TRANSFORMATIONS AT INTERNATIONAL CONGRESS IN MEXICO

In the XXXIII Latin American Congress of Sociology (ALAS), was launched the book "Global Socioecological Transformations. Post-pandemic society, climate change, nature and democracy", text that was edited by Dr. Jorge Rojas, CRHIAM associate researcher, and Dr. Klaus Dorre, academic from Friedrich-Schiller University, Germany.

The presentation took place on August 16th, in Mexico, in which Dr. Jaime Ríos, president of ALAS (Latin American Association of Sociology) participated with the opening greeting, Dr. Jorge Rojas, who commented on the topics addressed in the text, and Dr. (c) Patricio Silva, doctoral student in Environmental Sciences at UdeC, who also shared his reflections on the work (Figure 28).

Figure 28. Presentation of a book led by a CRHIAM researcher at the Mexican Congress.

CRHIAM RESEARCHER GAVE PRESENTATIONS AT THE INTERNATIONAL SOCIOLOGY CONGRESS AND THE ITESO INSTITUTE OF MEXICO

The associate researcher of CRHIAM, Dr. Robinson Torres, participated with two presentations in the framework of the XXXIII Latin American Congress ALAS, which this year was held in Mexico. Dr. Torres presented the topics "From the water market to the hydro-commons: A socio-environmental project for the 21st century in Chile" and "Andean hydrocosmologies in the face of extractivism: Cases of the Diaguita and Mapuche peoples in Chile and Wallmapu" (Figure 29).

In addition, the researcher gave the master conference "Imaginaries of water in Chile: between the market, the common good, the worldviews of native peoples and the role of universities in search of peace", at the Instituto Tecnológico y de Estudios Superiores de Occidente (ITESO) of the Jesuit University of Guadalajara, in the context of his trip to Mexico.

Figure 29. Dr. Robinson Torres gave two presentations in International Sociology Congress, carried out in Mexico.

CRHIAM POSTDOCTORAL RESEARCHER DEVELOPS IN THE USA RESEARCH TO OPTIMIZE THE USE OF WATER AND NUTRIENTS IN IRRIGATION OF FRUIT TREES

Globally, climate change and rising temperatures threaten to reduce the availability of surface water. In Chile, various studies have made projections of climate change and vulnerability and impacts of this phenomenon, which is why Dr. Camilo Souto Escalona, CRHIAM postdoctoral researcher, is conducting a study in the United States with the aim of contributing to the area of water and nutritional optimization in fruit trees (Figure 30).

This project seeks to investigate new approaches that integrate the use of new technologies in the management of water and nutrients with other environmental and cultural limitations in fruit trees. The research work is being guided by Dr. David Bryla, an Oregon State University adjunct professor and USDA investigator, and by Dr. Eduardo Holzapfel, a CRHIAM research associate.

The study will take place in a blueberry orchard with three varieties: "Duke", "Top Shelf" and "Aurora", recently transplanted (2022) at the Oregon State University Lewis-Brown Horticultural Research Farm in Corvallis, OR. With this information, the SEB-PW model was calibrated to simulate transpiration and evaporation from the soil. The advantage of this model is that it explicitly simulates evaporation from irrigated and non-irrigated areas.

Figure 30. CRHIAM postdoctoral researcher carried out an study in Oregon State University, USA.

WATER CRISIS WAS THE FOCUS OF THE TENTH VERSION OF WATER CONGRESS

As a space of excellence to present the latest innovations, technological advances and good practices in water management, the 10th International Congress on Water Management in Mining and Industrial Processes, Water Congress 2022, was held, an event that was organized by Gecamin, the Center for Water Resources for Agriculture and Mining (CRHIAM) and Kinneret Academic College of Israel, and also had the technical organization of Fundación Chile (Figure 31).

"Water crisis: threats, challenges and opportunities", was the motto of this year's congress, which was held from September 7th to 9th in a virtual mode. The event had 362 attendees, from18 countries and more than 110 participants from the mining industry. All this with the aim of knowing different challenges and experiences to face the scenario of water scarcity that affects the country.

CRHIAM also participated as a speaker in the pre-congress course. With the aim of providing a broad vision of the effects of climate change on the management and reuse of water in general terms in the territory, Dr. José Luis Arumí, CRHIAM principal investigator, taught the course "Groundwater: origin, characteristics and management", within the framework of the pre-congress courses of the Water Congess 2022.

The course consisted of three modules: "Groundwater in the hydrological cycle", "Natural and artificial groundwater recharge" and "Groundwater management in Chile". The course, which was developed on September 5 and had the participation of approximately 80 people.

Figure 31. Water Congress 2022 web page.

CRHIAM HEADED THE FIRST INTERNATIONAL SEMINAR ON RAINWATER MANAGEMENT AND CAPTURE

The diversification of water sources for its use in different uses is a vital adaptation measure to face the current scenario of water scarcity. In this context, the Water Research Center for Agriculture and Mining (CRHIAM), together with the Federal University of Pernambuco in Brazil, organized the "First International Seminar on Rainwater Harvesting and Management: The new water matrix".

The objective of the event was to talk and learn about the collection and management of rainwater in the world, Brazil and Chile. To this end, the seminar included the participation from Brazil of Dr. Sávia Gavazza, vice director of the Oil and Gas Research Institute of the Federal University of Pernambuco in Brazil; Ronaldo Mendes, president of the Brazilian Association for the Capture and Management of

Chuva Water; Sérgio Ayrimoraes, Superintendent of Water Resources Planning of the National Water Agency of Brazil; and Julio César Luz, Executive Director of the Brazilian Startup Pluvi (Figure 32).

They were joined from the Netherlands by Han Heijnen, President of the International Rainwater Harvesting Alliance. Meanwhile, from Chile, the speakers were Rodrigo Castillo, lawyer and collaborator of CRHIAM; Felipe Barriga, bioengineer and CRHIAM support engineer; Leonardo Fernández, co-founder of Cosecha Agua Chile; and Dr. Gladys Vidal, director of CRHIAM, who was the moderator of this activity.

During the seminar, the speakers discussed topics such as rainwater harvesting for human supply around the world, Brazil's experience in this matter and its contribution to water security, the use of this water in urban areas, the institutional framework and its management in Chile, quality of collected water and experiences, advances and limitations of rainwater collection in the country.

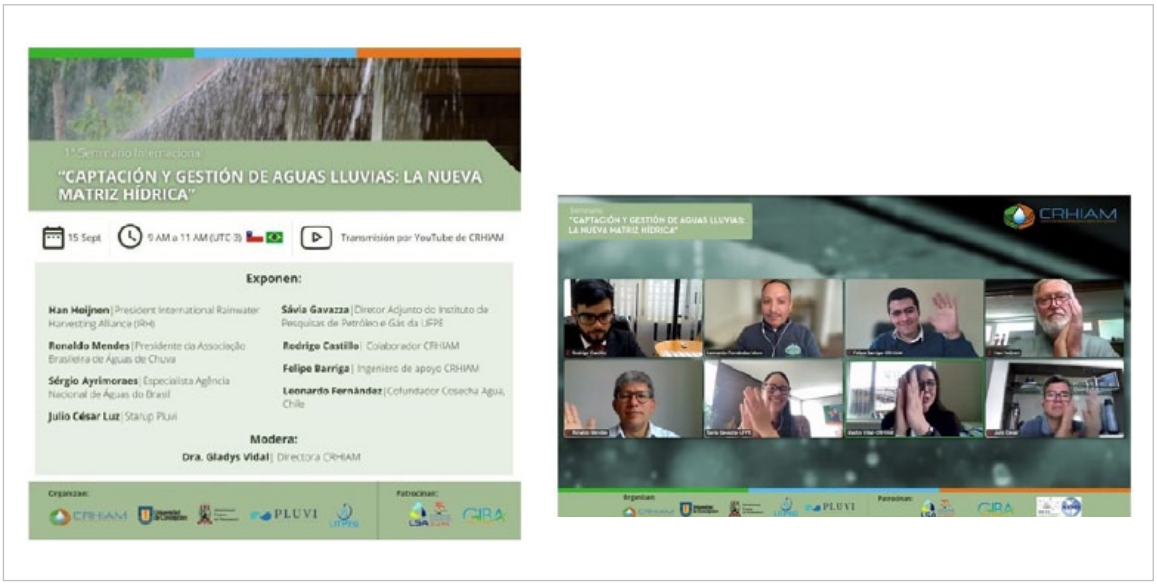


Figure 32. First International Seminar about rainwater harvesting.

CRHIAM PARTICIPATED IN THE INTERNATIONAL CONFERENCE ON ATMOSPHERIC RIVERS

From October 10th to 14th, the International Conference on Atmospheric Rivers, IARC 2022, was held, aimed at promoting the participation of researchers, professionals and students within the broad international community that works on this topic (Figure 33).

CRHIAM, together with the centers CR2, CW3E, Scripps Institution of Oceanography (UCSD, USA), the Department of Geophysics of the U. de Chile, Scientific Committee on Antarctic Research, Near-term Variability and Prediction of the Antarctic Climate System, MeteoData (Chile), O'Higgins University (Chile), among other institutions, were in charge of sponsoring this event.

Likewise, the main investigator of CRHIAM, Dr. José Luis Arumí, participated as a member of the ad-hoc implementation committee made up of an international and multidisciplinary group of researchers.

Figure 33. CRHIAM was part of the sponsoring group of International Conference carried out in Santiago, Chile.

CRHIAM ASSOCIATED RESEARCHER PARTICIPATED IN THE 29TH INTERNATIONAL SYMPOSIUM ON APPLIED GEOCHEMISTRY

Between October 23th and 28th, the 29th International Applied Geochemistry Symposium (IAGS 2022) called "Facing today's challenges using applied geochemistry" was held in Viña del Mar, where international researchers met to discuss these topics (Figure 34).

Dr. Oyarzún, CRHIAM associate researcher, made two presentations, in which he presented the studies "The Geochemical Anomalies of the Turbio River, Coquimbo Region, North Central Chile, and its Environmental and Economic Bearings" and "A coupled isotopic-geochemical assessment of hydrological dynamics in headwater Andean basins in north-central Chile". "Both works refer to hydrogeochemical issues. In the first, the data obtained from the chemistry of the waters and sediments of the Elqui river basin are discussed", comments the CRHIAM researcher.

Figure 34. Dr. Ricardo Oyarzún was part of International Symposium about geochemistry.

CRHIAM RESEARCHER PARTICIPATED IN THE 15TH BIENNIAL INTERNATIONAL CONFERENCE ECOBALANCE 2022

Dr. Patricio Neumann, CRHIAM associate researcher, traveled to Fukuoka, Japan, to present two investigations within the framework of the fifteenth biennial international conference, EcoBalance 2022 (Figure 35).

Dr. Neumann presented two investigations, one in oral format and the other as a poster, in which he addressed issues related to the environmental analysis of sanitary sludge management strategies and wastewater treatment technologies, in addition to exposing the importance of consider studies based on life cycle analysis in public policies regarding this topic.

In addition, the CRHIAM researcher participated as an instructor during the International Graduate School organized by the conference, where new collaboration networks are established and researchers interact with world leaders, in addition to staying updated with respect to global trends.

"One of the most interesting aspects was to observe the great importance given to environmental sustainability and to methods such as life cycle analysis in the productive sector of Japan. The incorporation of environmental criteria in the strategies of large companies is a topic that has been developed in this country for almost 20 years, forming an integral part of their activities even from the product design stage", pointed out Dr. Neumann.

The activity was carried out between October 30th and November 2nd, and more than 400 specialists in the subject participated, belonging to both the productive sector and academia.

Figure 35. CRHIAM Adjunct Researcher participated in International Conference carried out in Japan.

RESEARCHER OF THE IMDEA INSTITUTE VISITED THE UDEC WITH THE SUPPORT OF CRHIAM

Dr. Marco Vighi, a prominent academic and expert in ecotoxicology, came to Chile from Italy with the support of CRHIAM, to carry out training on topics such as drought, contamination and risk assessment in salmon farming" (Figure 36).

During his stay in Chile, he gave a conference in Concepción on "Effects of drought and chemical contamination on aquatic ecosystems", on Friday, November 4th, where he spoke about how water scarcity, aggravated by climate change and deficiencies in its management, is a worrisome problem worldwide. In addition, he conducted a course on "Environmental Pollutant Risk Assessment" for doctoral students and researchers, from November 7th to 11th, at the University of Concepción. In the city of Puerto Varas, on November 15th, a workshop was held on "Risk assessment for chemicals used in salmon farming".

Figure 36. Italian researcher visited Chile, given International Conference and Workshop about water pollution.

GERMAN SCHOLARSHIP HOLDER IS CARRYING OUT A STUDY ON THE LAJA RIVER THANKS TO THE SUPPORT OF CRHIAM

In November, the Fondap CRHIAM Center received a German student from Leibniz Universität Hannover (Figure 37), thanks to an agreement that this house of studies maintains with the University of Concepción. His stay was possible thanks to an exchange scholarship, which will allow him to spend six weeks in Latin America.

The intern is Zoe Bovermann, a civil engineering student and is in her last semester of the Master of Sciences, mention in Civil Engineering, for which she is developing a study called: "Multi-objective optimization of conflicting hydropower and irrigation water demands in the Chilean Laja River basin". Regarding her decision to travel to Chile to study the Laja River basin, Zoe Bovermann points out that "when I was looking for a topic for my master's thesis, I saw that the institute where I also study maintains a close collaboration with this university in the field of water resources".

His research work is focused on generating a model whose object of study is the Laja River and its catchment areas, in order to find adequate operating control curves to respond to the conflicts present in this area. To do this, it proposes to investigate the links between water (natural availability), energy (renewable energy production by hydroelectric energy), food (irrigated agriculture) and ecology (environmental flow to maintain the waterfalls), through a model that optimizes the use of water for different uses.

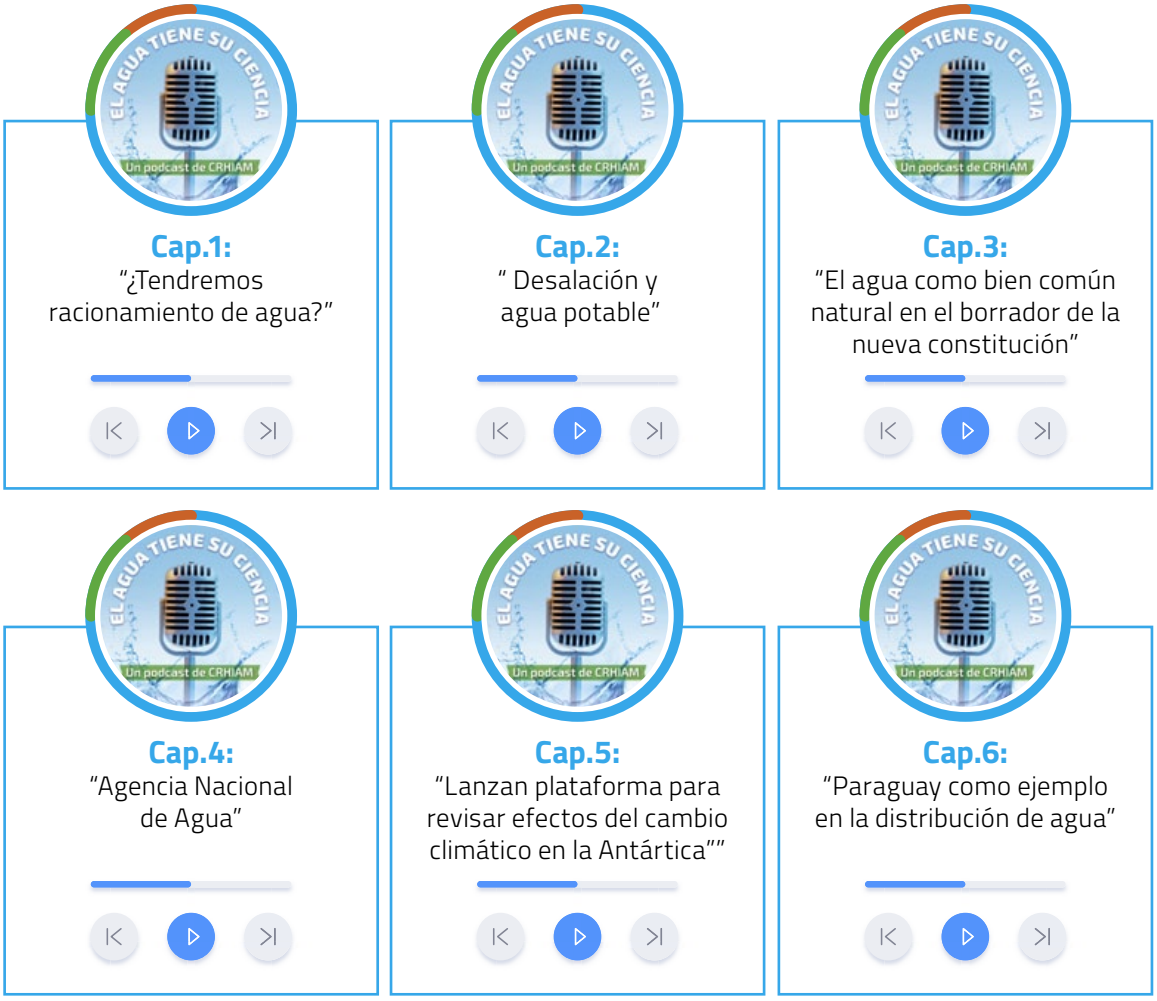
This master's thesis will include field trips, visits to reservoirs, practical and bibliographical research, among others. This research is under the supervision of Dr. Jorg Dietrich and has the participation of Dr. José Luis Arumí, principal researcher of CRHIAM and academic at the Universidad de Concepción.

Figure 37. German Master of Sciences student visited Chile with CRHIAM support.

6.3 CRHIAM Podcast: "El agua tiene su ciencia"

In 2022 the podcast focused on creating short, 5–10-minute capsules summarizing top water news stories. The third season had nine episodes (Figure 38), covering issues such as water rationing, desalination and drinking water, and water in the new constitution, among others. In August preparations for a new podcast season began (with its fortnightly broadcast beginning in September), with capsules focused on explaining CRHIAM's research topics as a way of making society more aware of the work carried out at CRHIAM (Figure 39).

Third Season



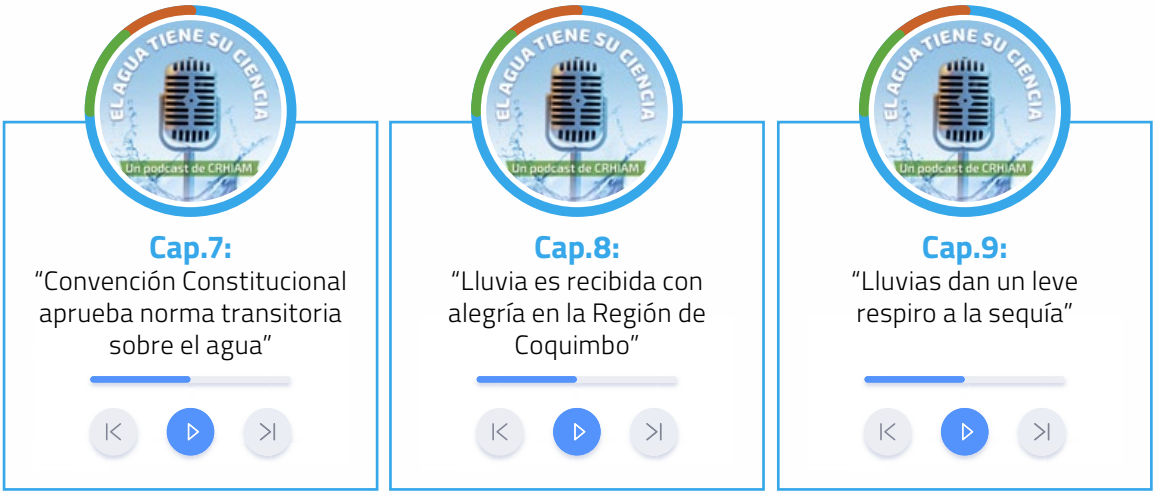


Figure 38. Podcast Third Season episodes.

Fourth Season

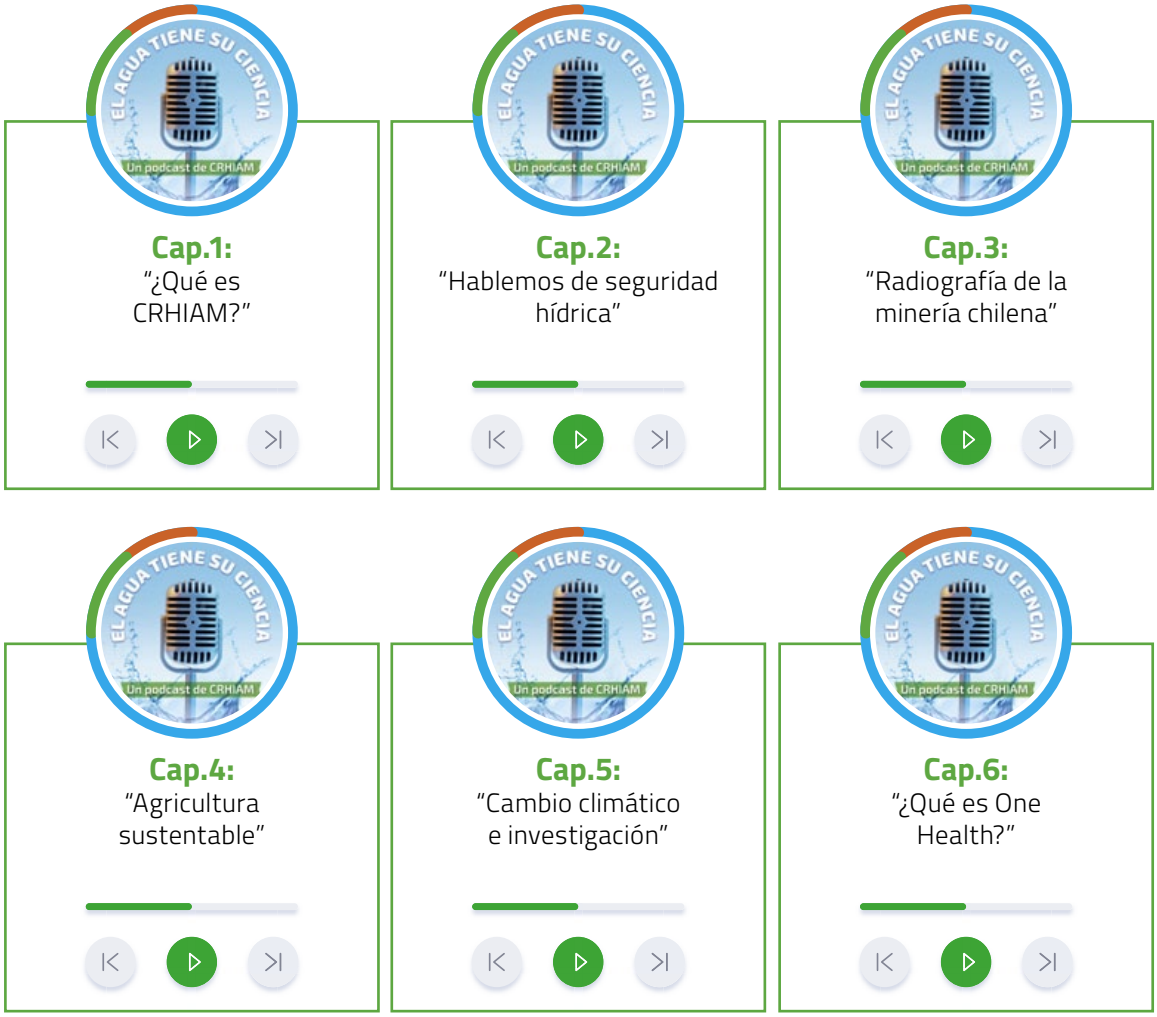


Figure 39. Podcast Fourth Season episodes.

6.4 CRHIAM Infographics 2022

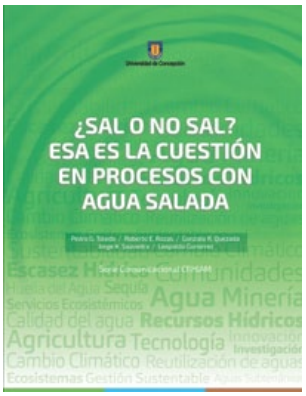
The infographics are based on the scientific evidence raised by our researchers. Below are the infographics published during 2022 (Figure 40).

Figure 40. CRHIAM Infographics 2022.

6.5 Outreach

2022 CRHIAM Communication Series

The CRHIAM Communication Series, which is intended to mobilize scientific evidence to stakeholders and society in general. In 2022 interdisciplinary work was intensified for the creation of the CRHIAM Communication Series volumes on different topics related to water resources, technology, governance, and management, among others (Figure 41), in easy-to-understand language for all audience levels. Seventeen CRHIAM Communication Series have been published this year. The authors of each volume belong to at least two different research lines to promote interdisciplinary work.

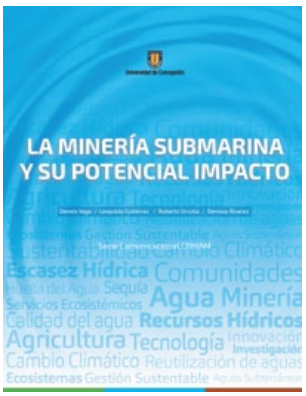


¿Sal o no sal? Esa es la cuestión procesos con agua salada

Autores: Pedro G. Toledo, Roberto E. Rozas, Gonzalo R. Quezada, Jorge H. Saavedra y Leopoldo Gutiérrez.

El fósforo como nutriente: perspectivas globales, ambientales y su aplicación en la agricultura

Autores: Valentina Carrillo, Gloria Gómez, Barbara Fuentes, Octavio Lagos y Gladys Vidal.



La minería submarina y su potecial impacto

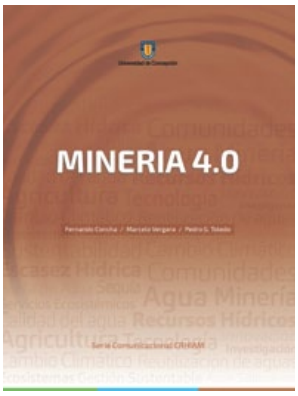
Autores: Dennis Vaga, Leopoldo Gutier arez, Roberto Urrutia y Denisse Álvarez.

Disputas por el agua: actores e instituciones del contexto urbano y rural

Autores: Rodrigo Castillo, Ma.Belén Bascur, Kimberly Iglesias, Diego Rivera, Amaya Alvez y Robinson Torres.

Minería 4.0

Autores: Fernando Concha, Marcelo Vergara y Pedro G. Toledo.



Calidad del agua y su uso en la minería

Autores: Andrés Ramírez, Leopoldo Gutiérrez y José Luis Arumí.

Uso de herramientas isotópicas para estudios de problemas hidrológico-Ambientales

Autores: Pía Urrea Olmedo, Ricardo Oyarzún Lucero, José Luis Arumí y Leopoldo Gutiérrez.

Uso de agua de mar en minería. Avances en el espesamiento de relaves ricos en arcillas

Autores: Francisco Pulgar, Ricardo I Jeldres, Fernando Concha y Pedro G. Toledo.

Calidad del agua recirculada en operaciones mineras. Mejoramiento mediante microesferas de vidrio químicamente funcionalizadas

Autores: Kevin Pérez Salinas, Ricardo Jeldres Valenzuela, Pedro G. Toledo y Leopoldo Gutiérrez.

Corre Litio que te pilla el Sodio

Autores: Pedro G. Toledo, Roberto E. Rozas, Rodrigo Yepsen y Leopoldo Gutiérrez.

Vulnerabilidad de cuencas: Estresores y desafíos

Autores: Loretto Arriagada, Diego Rivera, Roberto Ponce y Juan Munizaga.

Modelación matemática de sistemas biológicos: microalgas y bacterias para el tratamiento de aguas residuales

Autores: Fraçois Crouchett, Jineth Arango, Raimund Bürger y David Jeison.

Serie Comunicacional CRHIAM: Calidad ambiental de fuentes de agua potable de empresas de servicios sanitarios en Chile. Periodo 2014-2020

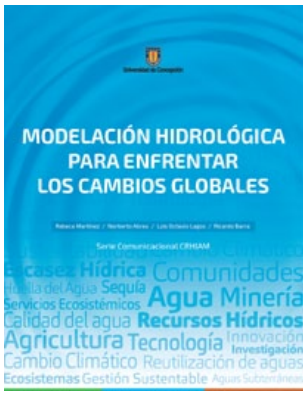
Autores: Centro de Recursos Hídricos para la Agricultura y la Minería (CRHIAM).

Litio ¿Recurso estratégico? Para saber y contar

Autores: Pedro G. Toledo, Omar Blas Alvarado, Roberto E. Rozas, Gonzalo Quezada y Leopoldo Gutiérrez.

Sustentabilidad de los sistemas de tratamiento de aguas servidas. Una mirada desde el análisis de ciclo de vida

Autores: Yannay Casas, Yenifer González, Gloria Gómez, Eduardo Holzpfel, Nicolás Arroyo y Gladys Vidal.



Modelación hidrológica para enfrentar los cambios globales

Autores: Rebeca Martínez, Norberto Abreu, Luis Octavio Lagos y Ricardo Barra.

Estudio comparado de la regulación de cosecha de aguas lluvias

Autores: Rodrigo Castillo, Felipe Barriga, Leonardo Fernández, Gloria Gómez Ma. José Ortega, Amaya Álvez y Gladys Vidal.

Figure 41. 2022 CRHIAM Communication Series

Communication of the scientific evidence generated by CRHIAM's researchers to society is among its main focuses. To this end, it carries out various scientific dissemination initiatives focused on the community, including schoolchildren, technical high school students, teachers, professionals, and society in general. The activities carried out by CRHIAM as outreach during 2022 are illustrated below.

CRHIAM RESEARCHER TEACHED A COURSE ON IRRIGATION IN FRUIT TREES FOR PEC CHILE

Dr. Eduardo Holzapfel, a researcher associated with CRHIAM, was in charge of teaching a course on fruit irrigation with an emphasis on cherry trees (Figure 42). This training was requested by the company PEC Chile de Curicó, within the framework of the Cherry Tree Management program.

The activity was carried out on December 28th, in online mode, for 50 farmers, who were able to learn more about water management in cherry trees associated with water demand, location of water application, frequency and irrigation times according to plant conditions and soil type.

Added to this is the fact that information was provided on irrigation systems for fruit trees, both superficial and pressurized, and what is the optimal type of irrigation according to the conditions of the land. In this line, costs associated with irrigation methods and their use restrictions were analyzed. Finally, the issue of irrigation efficiency and its effect on production was addressed.

Figure 42. Course on fruit irrigation with emphasis on cherry trees.

CRHIAM MEMBER VISITED SCHOOL OF TECHNICAL IRRIGATION IN BOLIVIA

Thanks to the inter-institutional cooperation between the WorldSkills Chile Foundation and the Education for Development Foundation FAUTAPO of Bolivia, the Technified Irrigation School was recently created at the José Martí Institute in the department of Chuquisaca. In this context, Dr. Felipe de la Hoz, community engagement coordinator of CRHIAM, was invited to visit the school facilities to verify their technical conditions.

In addition to the visit that took place from March 6th to 11th, Dr. de la Hoz added that last year he conducted a training course for teachers at the José Martí Institute on the hydraulics of technical irrigation systems, with the aim of updating their knowledge about this activity (Figure 43).

"There is interest and a need on the part of professionals and teachers in Bolivia, for continued support from CRHIAM and WorldSkills Chile in the process of implementation and continuous training of teachers, as well as, of support them in the process of creating teaching portfolios and effective training techniques with farmers", he pointed out

Figure 43. Irrigation technical visit to José Martí Institute in Bolivia.

SUSTAINABLE SELF-MANAGEMENT PROJECT IN PLAZA PERU CLOSED WITH DELIVERY OF GREEN SEAL TO A LOCAL RESTAURANT

After four months of execution, the project "Contributing through interdiscipline to sustainable cultural self-management of the iconic heritage neighborhood Plaza Perú, Concepción" ended its activities with the delivery of a green seal to the Penquista restaurant "La Cocina" (Figure 44). This initiative was developed by Karien García and Samuel Pérez, students of the Doctorate in Environmental Sciences at UdeC and CRHIAM students. Likewise, it was financed with the FAICC 2021 Culture Fund of the Municipality of Concepción, and had the collaboration of the Center for Water Resources for Agriculture and Mining CRHIAM, the Red Creativa Integral R.A.M.A, together with cultural groups such as All the theory of the Universe.

The mayor of Concepción, Álvaro Ortiz, was present at the closing ceremony, who pointed out that this type of initiative is in line with improving the administration of the premises of Plaza Perú, in order to generate more sustainable spaces. "We are talking about self-management, sustainability, that for example people with visual disabilities can also attend these premises, that pets can also be received, where the waste generated by this type of premises is also given a use that is much more than just throwing them in the trash," he said.

This project sought to strengthen the links between the inhabitants of the neighborhood and make the commercial offer more inclusive. "This initiative consists of promoting recycling, the conscious use of water, improving lighting, reducing ambient sound, or for example, blind or deaf-mute people can come and feel comfortable, welcome them with the language of signs and that they can access letters in braille. So we wanted to make the community feel part of the restaurant business model and make them aware of the environment they are in," explained Karien García.

In order to acquire the green seal, the tenants of Plaza Perú had to meet different milestones, among which the promotion of local commerce stands out, such as the purchase of their supplies from entrepreneurs in the region, the improvement of their lighting, the reduction of environmental noise and better management of water use.

Figure 44. Closure of a sustainable self-management project.

ELEMENTARY SCHOOL STUDENTS LEARNED ABOUT GLACIERS THROUGH INTERACTIVE ACTIVITIES

Within the framework of ANID's Cold-blooded Ring project: drivers of climate change refuge for glaciers and streamflow responses, elementary school students from Los Arrayanes and El Claro de Pucón schools were able to learn about concepts related to glaciers through five workshops developed by the Interactive Center for Sciences, Arts and Technologies, CICAT (Figure 45).

Participating in this project are Dr. Diego Rivera, CRHIAM principal investigator, and Dr. Mario Lillo, CRHIAM associate investigator. These workshops are part of the Earth Sciences content dissemination activity, called "The glacier rope: interactive experiences".

The conference was held at the Pucón campus of the Universidad de la Frontera, where the boys and girls learned about snow, volcanoes and rivers and their importance for the sustainability of ecosystems. It should be noted that this Ring project is an interdisciplinary research project in which specialists from various areas study the impact of climate change on mountain areas in the center and south of the country.

Figure 45. CRHIAM researchers participated in educational project about glaciers to elementary school students.

CRHIAM AND GIBA UDEC JOIN PAR EXPLORA BIOBÍO TO RECEIVE SCHOOL CLUBS

The Center for Water Resources for Agriculture and Mining (CRHIAM) and the Environmental Engineering and Biotechnology Group (GIBA UdeC) joined the initiative promoted by PAR Explora Biobío "School research and innovation".

Last Tuesday, June 28th, they received a group of 20 people, including students and professors, with whom they shared research experiences in relation to water resources. In particular, they visited the laboratories and the greenhouse, where boys and girls from 4th to 7th grade were able to ask questions and learn a little more about topics related to the work of their respective research clubs (Figure 46).

During the day, they learned a little more about water quality and how to measure its different parameters; as well as they learned more details about wetlands and their purifying functions.

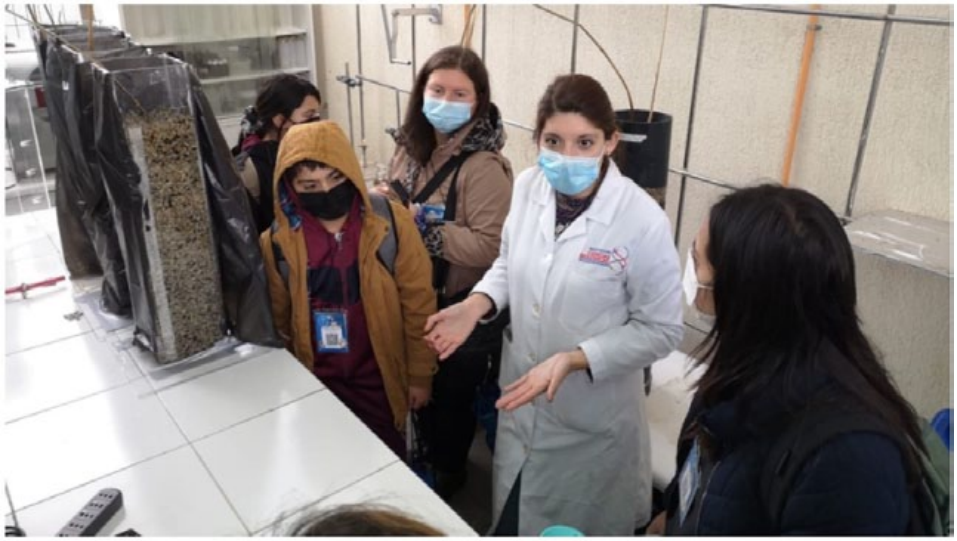


Figure 46. Sharing the experience of research in water resources to schoolchildren and teachers.

FARMERS FROM THE CENTRAL ZONE PARTICIPATED IN TALKS CARRIED OUT BY CRHIAM

A total of 23 farmers from PRODESAL and technical advisers from Placilla, Nancagua and San Fernando participated in talks prepared by the Center for Water Resources for Agriculture and Mining (CRHIAM), in which issues such as the water situation in Chile, institutions that manage water and technified irrigation (Figure 47).

"These talks are part of a requirement by the National Society of Agriculture and SNA Educa, who are developing a line of support for small-scale agriculture through talks on topics that contribute to the profitability and sustainability of their production systems," he explains. Dr. Felipe de la Hoz, community engagement coordinator of CRHIAM.

The National Society of Agriculture and SNA Educa requested technical support to carry out these presentations, so that in the future they can be replicated by teachers from SNA Educa establishments.

Figure 47. Educating farmers about water resources.

MORE THAN A HUNDRED SMALL FARMERS WERE TRAINED ON TECHNICAL IRRIGATION

With the purpose of teaching about the water reality of the country, optimizing irrigation and knowing more about the institutions linked to water, the community engagement coordinator of CRHIAM, Dr. Felipe de la Hoz, dictated the "Cycle of talks for small farmers: Technified irrigation and how to face the current water reality" (Figure 48), organized by the National Society of Farmers (SNA) and SNA Educa.

Figure 48. Flyers of talks on technical irrigation.

Dr. de la Hoz gave a presentation on three different topics, "Chile's water reality", "Water-related institutions" and "Technified irrigation", which he gave in four communes: Ovalle, San Felipe, Duao and Talagante, bringing together more than 100 people linked to local agriculture (Figure 49).

Figure 49. Participants of the training in technical irrigation.

CRHIAM RESEARCHER PRESENT ON GROUNDWATER MANAGEMENT TO RURAL EXTENSIONISTS FROM THE CENTRAL ZONE

With the purpose of educating and improving irrigation management carried out by professionals linked to this area, the National Irrigation Commission (CNR) developed the initiative "Training Program for professionals in the central zone in water resource management". This program included a technical seminar in the community of Olmué, in which the principal researcher of CRHIAM, Dr. José Luis Arumí, participated as a speaker (Figure 50).

"The objective of the activity was to train professionals in technical, legal and organizational aspects of water resources. The workshop in which I participated was of a technical nature and I had to do a training on two topics: use of groundwater and accumulators. In this last topic, I used the communication series and the new policy briefs developed by CRHIAM as support material", explained Dr. Arumí.

For the CRHIAM researcher, this initiative is especially relevant because "they are the professionals who generate irrigation project initiatives to favor peasant family farming, so the training directed by the CNR allows improving the assistance to these farmers."

The program is aimed at professionals or extension workers in the water resources area of INDAP and the Local Development Program (PRODESAL). It is executed through the University of Concepción and considers a budget of $480 million. It covers a total of 17 provinces and 123 communes, most of which have a high potential for the development of the agricultural and forestry sector and contribute strongly to the national GDP.

Figure 50. CRHIAM principal researcher trained to CNR professionals.

CRHIAM MEMBER GAVE A TALK ENTITLED "WHERE IS THE WATER?"

On August 25th, a talk was held called "Where is the water?" within the framework of the first edition of the Winter School of the Science League of the Universidad de Concepción the one that featured a presentation by CRHIAM member Yenifer González, who is an environmental engineer and doctoral student in Environmental Sciences at the University of Concepción.

"The purpose of this exhibition was to contribute to citizen environmental education", commented doctoral student Yenifer González, "these instances are important both for the community and for us as students, to communicate all the knowledge acquired and the interest for the investigation and care of our resources".

In the talk, topics related to the importance of water resources for communities and the ecosystem were discussed, relating the water resources available at the surface level and underground. In addition, data was shown on how this resource is distributed according to the different productive uses and the impact on availability due to climate change, together with the introduction of the concept of the Water Footprint and its values for everyday products.

The activity, which was open to the general public, was held in the Mancinelli auditorium of the Faculty of Biological Sciences of the Universidad de Concepción (Figure 51).

Figure 51. CRHIAM member given a talk highlighting the importance of water resources to communities and the ecosystem.

CRHIAM TRAINED TECHNICAL ADVISORS FROM COOPEUMO

With the objective of teaching about irrigation methods, on August 2th and September 22th, a training for technical advisors of the Cooperativa Campesina COOPEUMO was held in the commune of San Fernando. This activity was carried out by the community engagement coordinator of CRHIAM, Dr. Felipe de la Hoz (Figure 52).

The technical team and advisors of this cooperative were able to learn about pressurized irrigation methods (drip and micro-sprinkler), pumping and filtering equipment; know fertigation equipment used in fruit orchards; evaluate the discharge uniformity of an irrigation system by means of a field test; and analyze the different pumping and filtering equipment for pressurized irrigation.

This training sought to educate on how to improve the use of water resources, within the agricultural property, using a participatory methodology, in which each relevant point of the presentation, the attendees were consulted about their cases and experiences in said topics, which enriched the discussion and definition of the best practices to be used by farmers according to each case.

Figure 52. CRHIAM community engagement coordinator training to technical advisors of the Cooperativa Campesina COOPEUMO.

PRINCIPAL RESEARCHER OF CRHIAM GAVE A TALK ABOUT WATER SOURCES FOR THE MUNICIPALITY OF QUILLÓN

The principal researcher of CRHIAM, Dr. José Luis Arumí, gave a talk about the water sources for the Quillón commune, within the framework of the "1st Seminar on Water Deficit", organized by the Municipality of Quillón (Figure 53). In order to share with authorities and social leaders, the reality of the water deficit at a global and local level, the Directorate of Community Development through its Water Deficit program and the Municipal Environment Office organized a seminar to report on the progress, decisions and preventive aspects, related to said situation.

Dr. José Luis Arumi, spoke about the "Water sources for the Quillón commune", in which he recounted his experience of collaboration between municipalities and water resources management, while the CRHIAM researcher referred to the sources of water for Quillón.

The seminar was opened by the person in charge of the Municipal Environmental Office, Álvaro Mendoza, with the presentation "Water Deficit in Quillón: Drops of Reality", followed by Dr. Daniela Rivera, an academic from the Bío Bío University, who explained about " Experiences of collaboration between the academy and the municipality, in the management of water resources". The cycle of talks was closed by Dr. Rodrigo González, who referred to the determination of the microbiological quality of water for recreational use and reservoirs for human consumption.

Each talk included a round of questions from the attendees, who took advantage of presenting the reality they live on a daily basis, dealing with the problem of water deficit, the activity was carried out at the Antü tourist complex and was headed by Mayor Miguel Peña.

Figure 53. Dr. Arumí, CRHIAM principal researcher gave a talk on water sources to Municipality of Quillón commune.

FECI 2022: CRHIAM CELEBRATED SCIENCE WITH INITIATIVES IN DIFFERENT REGIONS OF THE COUNTRY

With talks, games and delivery of educational material on water, the Center for Water Resources for Agriculture and Mining (CRHIAM), joined the activities organized within the framework of the Festival of Sciences (FECI) 2022, which this year It took place from October 2nd to 9th (Figure 54).

The central theme of the 2022 version was the climate crisis and ecology, from a proactive perspective, valuing knowledge and reducing the uncertainty that this phenomenon causes in people. In this way, water was the central element of the festival, where it was sought to publicize its importance and raise awareness about its care.

Within this framework, CRHIAM was part of the initiatives organized by PAR Explora Ñuble, PAR Explora Biobío, PAR Explora RM Norte and PAR Explora RM Sur Oriente. On October 3th, CRHIAM postdoctoral researcher, Dr. Lucía Scaff, gave the talk "Climate and water in a resilient world", in the commune of Coihueco, Ñuble region. This activity was carried out by PAR Explora Ñuble through the discussion "Every drop counts".

Figure 54. CRHIAM actively participated in the 2022 Science Festival.

Figure 54 (Cont.). CRHIAM actively participated in the 2022 Science Festival.

CRHIAM AND ESSBIO HELD A CONFERENCE TO COMMEMORATE THE DAY OF COMMUNITY WATER MANAGEMENT

Dr. Patricio Neumann, associate researcher at CRHIAM, gave a talk on "Water scarcity and new water sources", within the framework of the commemorative activity carried out by Essbio for the Community Water Management Day in Chillán (Figure 55). During the talk given by Dr. Neumann, the fundamental principles of relevant phenomena for water management at the community level were exposed, such as drought, water scarcity and climate change, and general aspects of the new sources of water were discussed. water and the work that CRHIAM does in that area.

"Because water managers at the community level play a fundamental role in ensuring access to drinking water and sanitation services in rural areas, this being a role they assume voluntarily and without receiving any financial remuneration. It is important that these instances are held to recognize the great work they do and that benefits an important part of the country's population", comments the researcher.

The work that CRHIAM seeks to promote is that through the transfer of knowledge of relevant issues for water management, and knowledge about new technological developments, community management work can be facilitated or the doors to new development opportunities can be opened.

CRHIAM has a large number of researchers and collaborators in various areas that are relevant to water management in general, and specifically to what happens in rural areas, these activities being very important instances to build collaboration bridges with the community. This activity was aimed at community water managers, and issues related to the scientific principles of drought, water scarcity, climate change and new sources of water were addressed.

Figure 55. Conference to commemorate the day of community water management, Chillán.

CRHIAM PARTICIPATED IN THE OLYMPICS FOR TECHNICAL PROFESSIONAL STUDENTS WORLDSKILLS CHILE 2022

WorldSkills Chile is a championship to measure the skills of vocational technical training students in different disciplines, with the aim of promoting economic prosperity through education. In this new version, CRHIAM joined as a collaborator through the participation of the community engagement coordinator of CRHIAM, Dr. Felipe de la Hoz, who served as Chief Expert of the Technified Irrigation Skill, which consisted of designing the modules competence, design the evaluation guidelines for the experts and see all the input purchase efforts, supervise the evaluations of the teams by the experts, who had the responsibility of ensuring the correct development of the competences and ensuring the compliance with the rules of WorldSkills Chile (Figure 56).

The sectors evaluated were technology, industrial, food, information technology and sustainability. In the area of technical irrigation and agriculture, it brought together nine teams from different educational centers, with a total of 18 competitors and 11 expert evaluators. The event took place between November 14th and 18th, and measured the skills and competencies of students from high schools and technical institutes, under rigorous international standards, since WorldSkills is an organization with an international presence and headquartered in 83 countries, being in Chile, a unique foundation in its field and non-profit.

Figure 56. CRHIAM collaboration in a new version of WorldSkills Chile.

ÑUBLEDUCA 2022: CRHIAM EMPLOYEE PARTICIPATED MAKING A TALK ABOUT CLIMATE CHANGE

Dr. Denisse Álvarez, a CRHIAM collaborator, gave a talk about the natural and anthropic forces that climate changes generate and the impact that current global warming has on water resources, this, framed in the first version of the Ñubleduca 2022 seminar, organized by the Seremi de Medio Ambiente de Ñuble.

The talk given by Dr. Álvarez was entitled "Climate change and water", where she presented scientific evidence regarding the subject and shared the experiences of how some concepts related to freshwater systems have been brought to the classroom (Figure 57). They seek to publicize the ecological value of these ecosystems and the services they can provide. In the Ñubleduca 2022 seminar, various regional authorities participated, in addition to the Youth and Children's Symphony Orchestra of the San Ignacio commune, who performed well-known pieces of classical music.

This seminar had the theme "Climate Change: pedagogical learning opportunity" and was aimed at teachers and managers of establishments that participate in the National System of Environmental Certification for Educational Establishments (SNCAE). This activity was developed in the Aula Magna of the Universidad del Bío-Bío de Chillán, Campus Fernando May, in which more than 60 people also participated.

Figure 57. Talk about climate change and their impacts on the water resources.

STUDENTS FROM SAN PEDRO DE LA PAZ LEARNED ABOUT ENVIRONMENTAL CARE

The member of CRHIAM, Dr. Valentina Carrillo, participated in the VII Scientific Chocolate, which consisted of a work table and conversation with young people from Liceo Los Andes, Escuela Eliezer, Colegio Particular Manquimavida, Colegio Santa Bernardita, Colegio San José and Colegio San Andrés (Figure 58). In the VII version of the Scientific Chocolate, the topic to be discussed was "Water Crisis: How do we recover our waters?", with the purpose of promoting a culture of care for the environment, considering the different problems that affect local and global ecosystems, using information and communication technologies (ICT's) in the dissemination of these topics.

"Activities like these are very beneficial for students, since it brings scientists closer to students and gives relevance to what they learn, since they interact directly with people who study the environment," said Dr. Carrillo, also adding that it is necessary to "bridge the gap between scientists and students, in order to inspire young people and involve them more in what they are taught."

The activity took place on Friday, November 4th, in person at the Liceo Los Andes, with the participation of various scientists related to water resources issues and a total of approximately 40 students.

Figure 58. CRHIAM participated in VII Scientific Chocolate, organized by Liceo Los Andes.

STUDENTS FROM THE MUNICIPALITY OF LLICO LEARNED ABOUT THE HYDROLOGICAL CYCLE

To disseminate and value science in a playful and close way, the VIII version of the Llico Scientific Fair and Conference was held on November 8th: "From reflection to action: Innovating for a sustainable world", an initiative that is organized by the Filidor Gaete de Llico High School and the INCAR Center (Figure 59).

The initiative had the participation of the CRHIAM Center and different institutions, which participated through workshops, talks and stands for scientific dissemination. Felipe Barriga, CRHIAM support engineer, shared with the students about the country's water situation with the talk "The journey of a drop of water", where they were able to learn about the hydrological cycle, the importance of water quality and learn about part of the work carried out by the Center.

The sessions were also attended by the Department of Oceanography of the Universidad de Concepción (UdeC) with its careers in Marine Biology and Engineering in Marine Biotechnology and Aquaculture, the Laboratory of Marine Biotoxins of the UdeC and PREGA.

Figure 59. CRHIAM participated in VIII version of the Llico Scientific Fair.

STUDENTS FROM THE MUNICIPALITY OF CUREPTO LEARNED ABOUT THE ECOSYSTEM AND THE BIOSPHERE

The PhD student in Environmental Sciences and member of CRHIAM, Yenifer González Ortiz, gave two talks entitled "The Earth and its functional processes" at the Ana Luisa Espina Rivero School in the Curepto commune, in the Region of the Maule.

These talks addressed concepts such as the biosphere, ecosystems and the processes that occur within them, such as the interactions between organisms, populations and communities. In addition, the concept of biomes and which ones are predominant in our country was integrated.

To bring the concepts closer to the students, examples of hydrographic basins were used showing local models with the predominant water bodies in the Maule region, in order to involve them more in learning. These presentations brought together a total of 45 students and were held in two talks, the first aimed at children from first to fourth grade and the second for students from fifth to eighth grade (Figure 60).

Figure 60. Curepto school children learned about ecosystems and biosphere.

6.6 Other Activities Organized by CRHIAM in 2022

IRRIGATION AND DRAINAGE IN FRUIT TREES: CRHIAM PRESENTED A BOOK THAT PROMOTES THE SUSTAINABLE USE OF WATER IN FRUIT GROWING

Among the productive factors that a farmer controls, irrigation is one of the least known and least cared for in agricultural production. Precisely to present and develop the concepts related to the sustainable use and optimal management of water resources, the manual "Irrigation and drainage in fruit trees" was executed, a text prepared by the Center for Water Resources for Agriculture and Mining (CRHIAM), with the support of the Foundation for Agrarian Innovation (FIA), of the Ministry of Agriculture, and whose launch took place on December 15th in virtual mode (Figure 61).

The activity included the participation of one of the authors of the text, Dr. Eduardo Holzapfel, associate researcher at CRHIAM and professor emeritus at the Faculty of Agricultural Engineering at the University of Concepción; and Maurice Streit, Agricultural Engineer and Agricultural Innovation Executive of the FIA, who commented on the text. Likewise, Dr. Elías Fereres, world authority in the field of water management in agriculture and professor emeritus at the University of Córdoba, was also invited to the panel, who commented on the importance of this manual through a video.

Figure 61. Book launched titled "Irrigation and drainage in fruit trees".

CRHIAM CONVENED CONSTITUENT CONVENTIONALS TO DEBATE ABOUT WATER

With the presence of the conventional constituents Amaya Alvez, Andrés Cruz, Tammy Pustilnick and Loreto Vidal, the Center for Water Resources for Agriculture and Mining (CRHIAM) held the seminar "Conversations on science and public policies: water in the new Constitution" (Figure 62).

The team of researchers from the center of excellence, led by the Universidad de Concepción, presented the scientific evidence they have gathered in these eight years of work, emphasizing the context of climate change and water scarcity that the country is experiencing today. In addition to the different social conflicts that are generated by the lack of this resource and the challenges to face the water crisis. In the discussion, some citizen participation mechanisms were also announced, through the presentation of popular initiatives of constituent norms.

Figure 62. CRHIAM organized the seminar "Conversations on science and public policies: water in the new Constitution".

CRHIAM COORGANIZED II WORKSHOP FOR YOUNG RESEARCHERS IN AGRONOMIC SCIENCES

Young researchers from the agri-food, forestry and environmental areas met on January 11th and 12th to participate in the II Workshop for Young Researchers in Agronomic Sciences (WJICA), a meeting organized by the Faculty of Agronomy of the University of Concepción, sponsored by of CRHIAM (Figure 63).

The Workshop, which this year was held under the theme "New Challenges towards sustainable agriculture", was attended by 50 researchers, who came to the Termas de Catillo, located in Parral, to present their scientific work to their peers. and discuss their research. The presentations were made simultaneously online.

Figure 63. Workshop "New Challenges towards sustainable agriculture", coorganized by CRHIAM.

FONDAP CRHIAM CENTER HELD A CONVERSATION ON THE IMPORTANCE OF GROUNDWATER

This activity was part of the initiatives that CRHIAM has prepared to celebrate World Water Day, which this year aims to make visible the value of groundwater resources (Figure 64).

Making known and highlighting the importance of groundwater for life on the planet was the focus of the discussion "Groundwater: making the invisible visible", an activity organized by the Water Research Center for Agriculture and Mining (CRHIAM) , which is part of the annual initiative "Water Forums: Research on Water Resources at the Service of the Community", which seeks to create awareness about the importance of caring for water resources.

Figure 64. Water Forums 2022, organized by CRHIAM to celebrate World Water Day.

CRHIAM RESEARCHERS LAUNCHED BOOK ON THE COMMON GOODS

"Common goods and biocultural diversity in times of crisis: water scarcity, pandemic and climate change" is the title of the work promoted by a group of researchers and academics from the University of Concepción, made up of Dr. Jorge Rojas Hernández, Patricio Silva Ávila, Dr. Ricardo Barra, Dr. Ricardo Figueroa, Dr. José Luís Arumí and Dr. Gunhild Hansen-Rojas.

The execution of this book was supported by the Water Research Center for Agriculture and Mining (CRHIAM), and represents a multi and interdisciplinary effort to study and approach traditional local knowledge and practices that have historically been present in Chile, Latin America and the world. The presentation of the book featured comments from Dr. Andrea D´Atri, an academic from the National University of La Pampa (Argentina), along with two of her co-authors, Dr. Jorge Rojas Hernández and Dr. Ricardo Barra, both CRHIAM researchers (Figure 65).

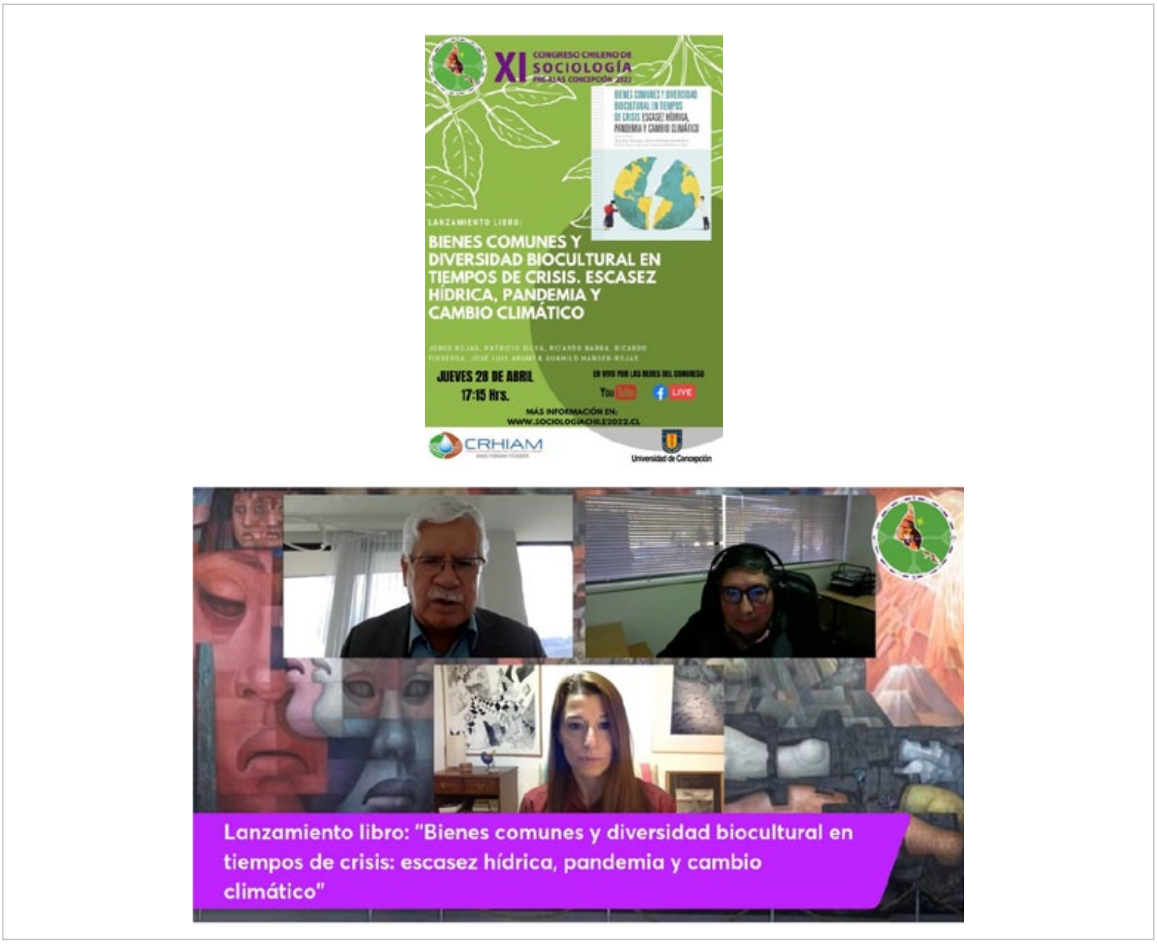


Figure 65. Book launched titled "Common goods and biocultural diversity in times of crisis: water scarcity, pandemic and climate change".

CRHIAM PRESENTED BOOK ON ASSESSMENT OF MICROBIAL METABOLISM

The treatment of industrial effluents and wastewater represents a constant challenge for the sanitation industry. In this context, CRHIAM researchers prepared the book "Evaluation of microbial metabolism for the monitoring and optimization of biological systems for the treatment of industrial effluents and wastewater", a work that was launched on May 11th through YouTube (Figure 66).

The event was attended by its editors, María José Ortega, researcher at the Environmental Engineering and Biotechnology Group (GIBA) at UdeC, Dr. Gladys Vidal, director of CRHIAM, and Dr. José Luis Campos, associate researcher at the Center. They were joined by Edson Landeros, planning manager of Aguas Andinas, who was in charge of presenting the book.

Figure 66. Book launched titled "Evaluation of microbial metabolism for the monitoring and optimization of biological systems for the treatment of industrial effluents and wastewater".

CRHIAM STUDENTS AND POSTDOCTORAL RESEARCHERS GATHERED TO PRESENT THEIR RESEARCH WORK

On May 17th and 24th, the IV Meeting of CRHIAM Postdoctoral Students and Researchers was held, an activity that has been consolidated as a space for socializing their thesis and research work. This year, the meeting brought together 41 participants from different cities in the country, who connected via Zoom during both days (Figure 67).

All the works presented were evaluated by a committee made up of CRHIAM collaborators and members of the operations team, who were in charge of scoring the originality and structure of each presentation. This, with the aim of choosing the best exhibitions in three categories: undergraduate, postgraduate and postdoctoral.

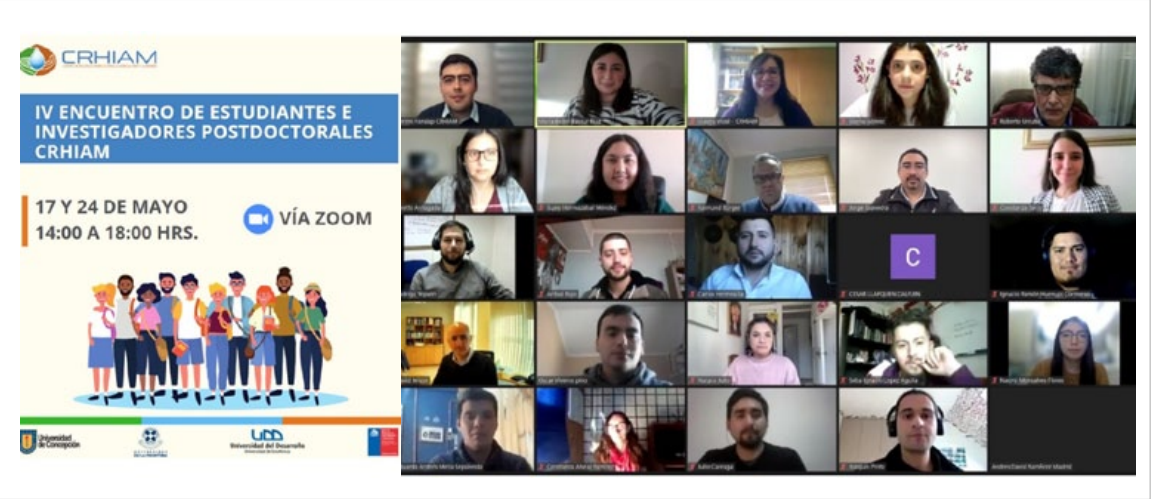


Figure 67. CRHIAM organized the "IV Meeting of CRHIAM Postdoctoral Students and Researchers".

WATER PLANTING AND HARVESTING CONGRESS BROUGHT TOGETHER NATIONAL AND INTERNATIONAL EXPERTS

Knowing, recovering and valuing ancestral practices such as planting and harvesting water was the purpose of the "Second Chilean Congress and First International Congress Planting and Harvesting Water: An Ancestral Water Management System" (Figure 68), an activity in which the CRHIAM principal researcher Dr. José Luis Arumí participated as a member of the scientific committee.

On this occasion, the CRHIAM researcher coordinated two round tables and presented a keynote talk entitled "A methodology for mapping ecosystems dependent on groundwater to demonstrate the contribution of SyCA". In addition to this, he presented the progress of the thesis "Water planting and harvesting practices as a mitigation measure against Climate Change" that he develops together with Karina Painenao, who is also a CRHIAM thesis student.

Figure 68. CRHIAM was the coordinating institution of congress about planting and harvesting water.

CRHIAM LAUNCHED BOOK ABOUT LIFE CYCLE ANALYSIS

"Water scarcity and the various environmental crises make it urgent to search for methodologies that allow projecting a more sustainable development. In this context, the Water Research Center for Agriculture and Mining (CRHIAM) developed the book "Life Cycle Analysis. Foundations and Applications to the Sustainable Management of Water Resources", text that was launched on June 14th in a virtual activity through the Center's YouTube channel (Figure 69).

The launch was attended by the three editors of the book, the director of CRHIAM Dr. Gladys Vidal, the associate researcher at the Center Dr. Patricio Neumann, and from Spain, Dr. Almudena Hospido, full professor at the University of Santiago de Compostela, who was in charge of presenting the text.

Figure 69. Book launched titled "Life Cycle Analysis. Foundations and Applications to the Sustainable Management of Water Resources".

CRHIAM COORGANIZED A MATHEMATICAL WORKSHOP WITH THE CI²MA CENTER

On July 5th and 6th, the workshop "Mathematical modeling and simulation for bioprocesses, wastewater treatment and mineral processing" was held, an event that brought together specialists in mathematical analysis from different universities in the country, who addressed topics such as the flotation process in mining and wastewater treatment (Figure 70).

This activity was organized by Drs. Fernando Betancourt and Raimund Bürger, researchers at the Center for Research in Mathematical Engineering (CI²MA) of the Universidad de Concepción and the Fondap CRHIAM Center, with the support of the Ring project "New models of flotation in the mining industry: simulation, experimental validation, and prediction tools for treatment of complex ores" (ANID/ACT210030) and the Fondecyt project 1210610.

Figure 70. CRHIAM organized seminar about mathematical modeling and simulation for bioprocesses.

CRHIAM PRESENTED A BOOK ON THE SEARCH FOR ANCESTRAL WATER IN NORTHERN CHILE

"Water scarcity and the various environmental crises make it urgent to search for methodologies that allow projecting a more sustainable development. For this, the study of ancestral hydrotechnologies is crucial to guarantee a sustainable future. In this context, Dr. Sebastián Videla, together with CRHIAM, developed the book "In search of ancestral water in the semi-arid and arid north of Chile", a text that was launched on 29th August in a virtual activity through the Center's YouTube channel (Figure 71).

The launch was attended by the book's editor, CRHIAM Director Dr. Gladys Vidal, the academic from the La Molina Agrarian University of Peru, Ronald Ancajima, who was in charge of presenting the text, and the author Dr. Sebastián Videla, who is also dean of the Faculty of Engineering at the Universidad Católica de Temuco.

Figure 71. Book launched titled "In search of ancestral water in the semi-arid and arid north of Chile".

"WATER STORIES": CRHIAM CENTER LAUNCHED A BOOK OF STORIES WITH WATER AS THE LEADER

A total of 47 stories make up "Water Stories", a text that was born from the short story contest carried out by the ANID CRHIAM Center during 2021. For this, the community was invited to write their stories related to water, as a way to connect with the dreams, concerns, challenges and memories that exist in relation to this vital element.

The launch took place on September 13th at the Espacio MAS auditorium of the Universidad de Concepción, and was attended by the Science, Technology, Knowledge and Innovation Seremi (CTCI) of the South Central Macrozone, Dr. Sofía Valenzuela, who spoke about the importance of linking science with the community (Figure 72). The Penquista illustrator Pamela Murtilla was also present, who told the attendees how the creative process of graphing each of the stories that are part of this work was.

Figure 72. Book launched titled "Water Stories".

CRHIAM JOINS FECI 2022 WITH A TALK ON DIVERSITY OF WATER SOURCES

CRHIAM's support engineer, Felipe Barriga, gave the talk "Importance of diversifying water sources" in the context of the 2022 Science Festival organized by Ministry of Science, Technology, Knowledge and Innovation in the program of Public Science to celebrate the science month (Figure 73).

During the talk, which was broadcast on CRHIAM's Youtube channel, engineer Barriga referred to surface and underground water sources, the changes in quality and quantity they have suffered, and the importance of a significant risk in the scarcity scenario water crisis facing Chile and the world.

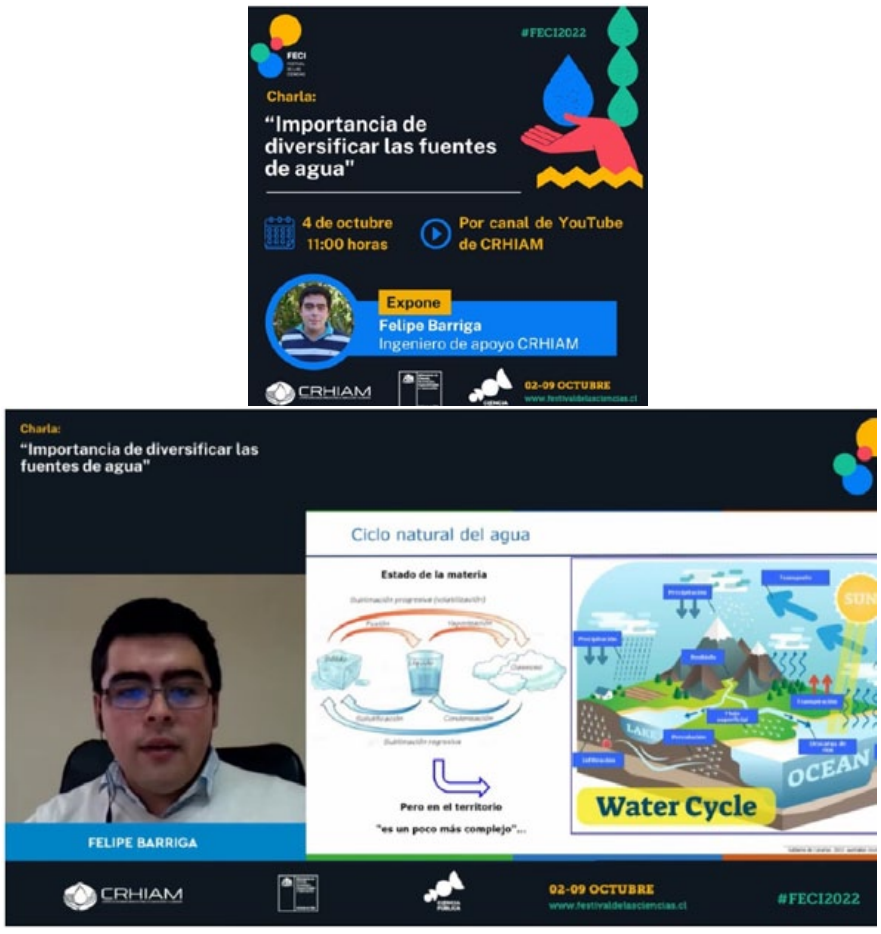


Figure 73. Talk in the framework of science month.

CRHIAM CO-ORGANIZED THE XVI NATIONAL CONGRESS OF LIMNOLOGY

The Chilean Society of Limnology (SCL) brings together all those interested in advancing knowledge of the processes and interrelationships of continental aquatic ecosystems (Figure 74).

This year the XVI National Congress of Limnology was held in the city of Coyhaique, Aysén Region, between October 11th and 14th, 2022. The event was supported by different institutions and CRHIAM participated as co-organizer of the activity.

Figure 74. CRHIAM participated as co-organizer in a new version of the national limnology congress.

Below you can see more information about each of the talks organized by CRHIAM within the framework of the 2022 Talk Cycle.

WATER REGULATION AND CONSTITUENT PROCESS MARKED THE BEGINNING OF THE CRHIAM 2022 TALK CYCLE

One of the issues that has marked the debate in the preparation of the new Constitution for Chile has been how water will be managed and whether priority uses will be established, especially in the context of the water crisis that the country is experiencing. To publicize the advances in this matter and the trends in comparative constitutional law, the first Cycle of Talks CRHIAM 2022, precisely addressed this topic, with the presentation "Regulation and management of water in the constituent process" (Figure 75).

The talk was given by the Center's support lawyer and research assistant, Rodrigo Castillo, who spoke about the protection of waters in the international arena, the Latin American scenario, and what the main conventional initiatives in water matters have been. In this regard, Castillo explained that there is a broad consensus on the incorporation of new elements to the constitutional statute of waters, in at least three fields of constitutional regulation.

Figure 75. Talk "Regulation and management of water in the constituent process".

CYCLE OF TALKS CRHIAM ADDRESSED LOCAL EXPERIENCES OF WATER GOVERNANCE

The May presentation of the CRHIAM Talk Cycle unveiled a monitoring tool that aims to strengthen the participation of local communities in water governance in their territories. This is SIMOL, which was generated within the framework of the Fondef project "Monitoring system for local participation in integrated watershed management" (Figure 76).

This talk was given by Dr. Marcela Salgado, a CRHIAM collaborator, who participated as a researcher in this project, in which CRHIAM researchers, Dr. Diego Rivera and Dr. Mario Lillo also participate.

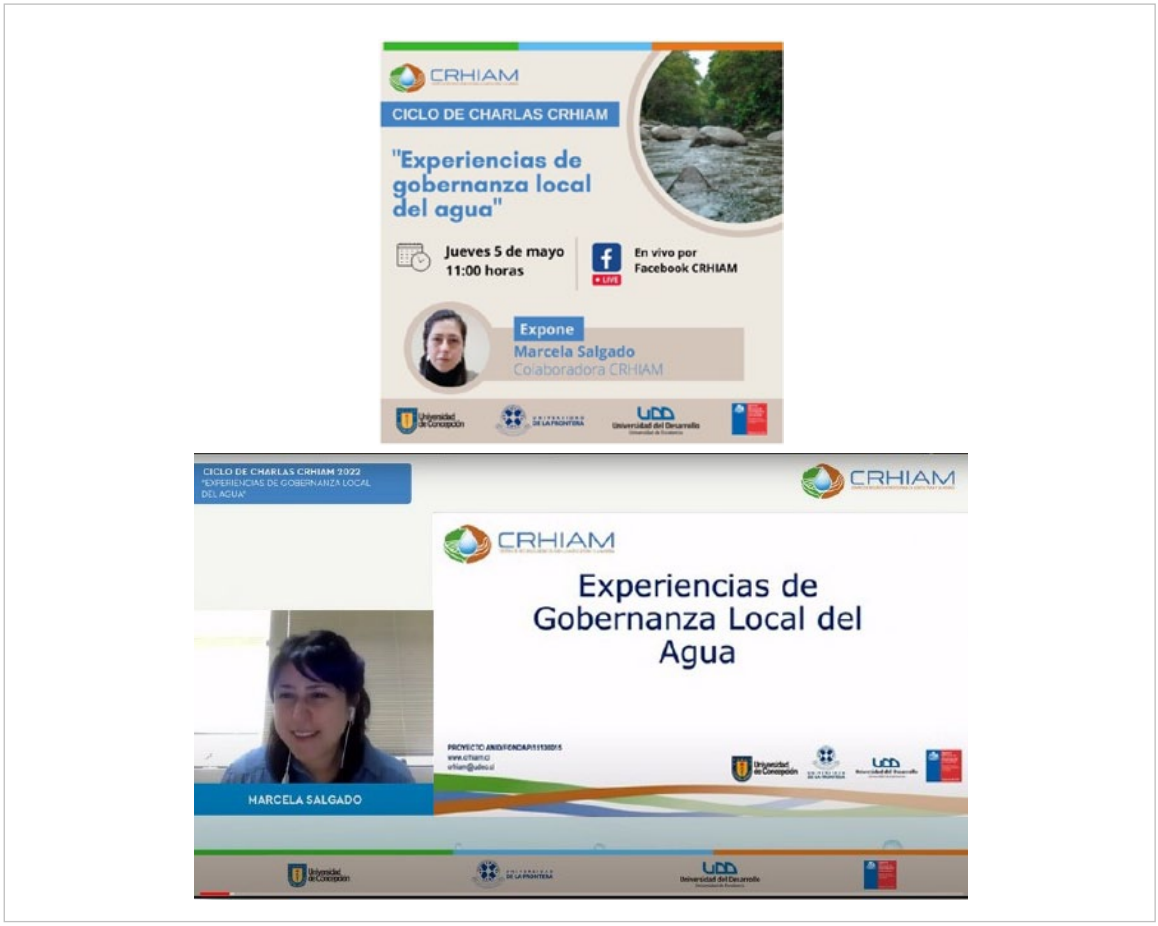


Figure 76. Talk "Local water governance experiences".

CYCLE OF TALKS CRHIAM PRESENTED STUDY ON ENVIRONMENTAL CONDITIONS OF LAKE LAJA

"Fossil pigments and environmental conditions in the Laja oligotrophic lake in the Chilean Andes" was the topic addressed in the CRHIAM Talk Cycle, which was held on June 2nd through the Center's Facebook fan page (Figure 77). The presentation was given by Dr. Lien Rodríguez, CRHIAM collaborator and Researcher at the Faculty of Engineering, Art and Design of the Universidad San Sebastián.

In the talk, he presented evidence on how the interactions between climate change, ozone depletion and ultraviolet radiation affect aquatic ecosystems.

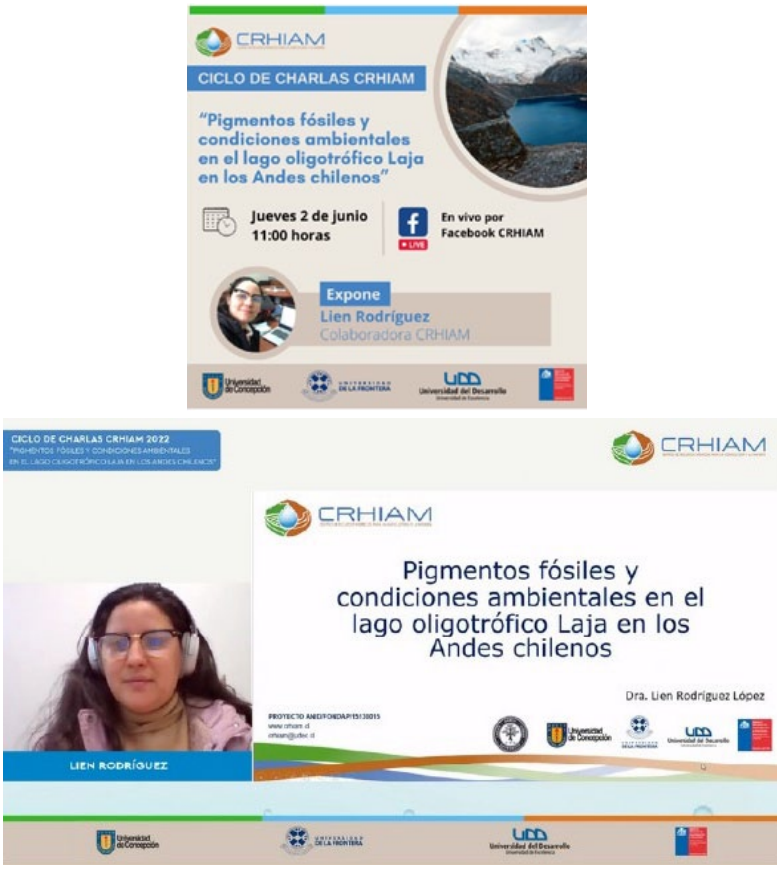


Figure 77. Talk "Fossil pigments and environmental conditions in the Laja oligotrophic lake in the Chilean Andes".

SERIES OF TALKS CRHIAM PRESENTED STUDIES ON THE EFFECTS OF SEAWATER ON MINING PROCESSES

Water scarcity has forced many productive activities to seek new sources of water, as is the case of desalinated water in mining. However, the presence of salts causes effects that are not yet fully understood, so the study of this type of phenomenon at different scales is crucial for a better understanding of how these new water sources affect or favor these processes.

In this context, the July CRHIAM Cycle of Talks "Experiments, artificial vision and simulation in flotation of minerals with sea water" was held, a presentation made by Dr. Jorge Saavedra, who was a CRHIAM postdoctoral fellow and is currently a collaborator of our center (Figure 78).

Figure 78. Talk "Experiments, artificial vision and simulation in flotation of minerals with sea water".

CYCLE OF TALKS ADDRESSED THE USE OF LAKE SEDIMENTS AS CLIMATE CHANGE ARCHIVES

"Lacustrine sediments and their use as archives of past climatic and environmental changes" was the topic addressed in the CRHIAM Talk Cycle, which was held on August 4th through the Center's Facebook page. The presentation was given by Dr. Denisse Álvarez, CRHIAM collaborator (Figure 79).

In the talk, the researcher explained the changes that occur in lagoons and lakes over time, both due to anthropological intervention and naturally.

Figure 79. Talk "Lacustrine sediments and their use as archives of past climatic and environmental changes".

CYCLE OF TALKS ADDRESSED VULNERABILITY TO GLOBAL WARMING AND THERMAL CHANGES IN FRESHWATER BODIES DUE TO CLIMATE CHANGE

"Thermal regime and freshwater ecosystems: knowledge and vulnerability to global warming" was the topic addressed in the CRHIAM Talk Cycle, which was held on September 1st through the Center's Facebook page. The presentation was given by Dr. Pablo Pedreros, CRHIAM collaborator (Figure 80).

In the talk, the researcher exposed the changes that occur in the lagoons and lakes due to climate change, how temperatures affect their ecosystems and thermal variation. The study presented by Dr. Pedreros presents an analysis of how climate change affects the biodiversity of freshwater bodies, the importance of studying temperature and the need to know how these functions. In addition, he stressed that they are "knowing the thermal sensitivity would be essential to predict and project the vulnerability of these water systems".

Figure 80. Talk "Thermal regime and freshwater ecosystems: knowledge and vulnerability to global warming".

CYCLE OF TALKS RAISED THE IMPORTANCE OF LIFE CYCLE THINKING IN DECISION MAKING

"Importance of life cycle thinking in decision-making" was the topic addressed in the CRHIAM Talk Cycle, which was held on October 6th through the Center's Facebook page. The presentation was given by Dr. Yannay Casas, CRHIAM associate researcher (Figure 81).

In the talk, the researcher spoke about the life cycles of products, the importance of considering these processes in decision-making to be more sustainable and where people are located in these stages and the responsibility to decide consciously. The study presented by Dr. Casas, presents an analysis of how the life cycle of the products and the knowledge of this, can contribute to better face the management of waste, water scarcity, water reuse, among other things. In addition, he stressed that "we can decide, based on the knowledge we have, in order to generate changes".

Figure 81. Talk "Importance of life cycle thinking in decision-making".

CYCLE OF TALKS IN NOVEMBER RAISED THE IMPORTANCE OF WATER QUALITY IN MINING

"Implications of water quality in mining" was the topic addressed in the CRHIAM Talk Cycle, which was held on November 3th through the Center's Facebook page.

The presentation was given by Dr. Andrés Ramírez, CRHIAM collaborator (Figure 82). In the talk, the researcher spoke about water in mining, how water resources are used and how they seek to advance to improve water reuse in this industry. The study presented by Dr. Ramírez, presents an analysis of how water influences the entire mining process, both in the extraction and in the collection of minerals. In addition, he raised the importance of the reuse of water in the industry to face water scarcity, among other things.

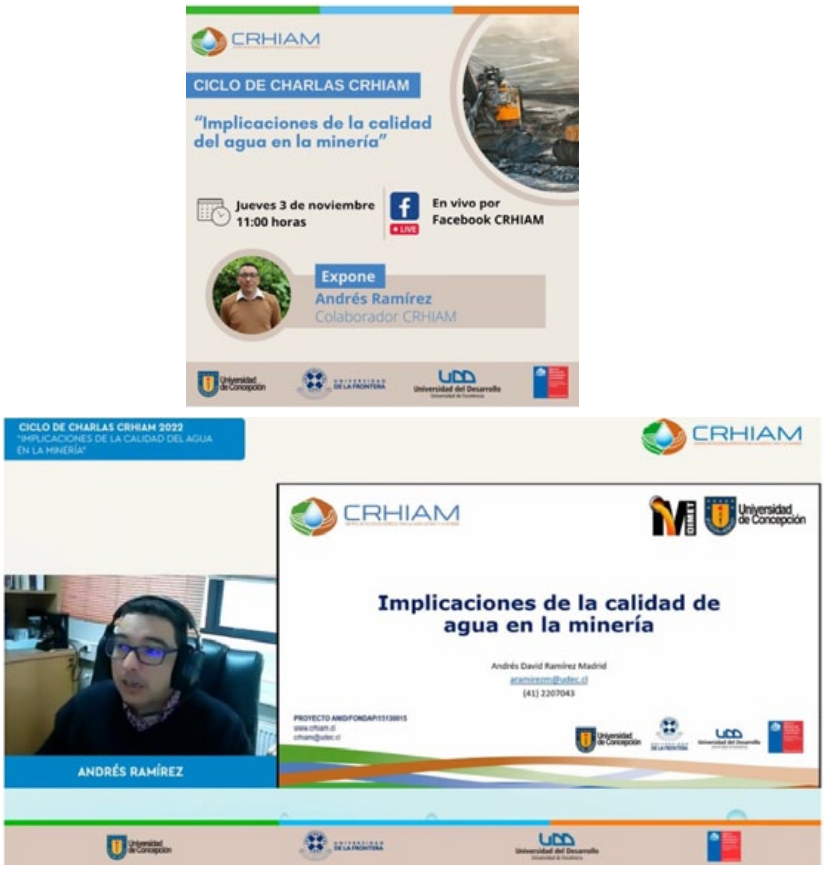


Figure 82. Talk "Implications of water quality in mining".

CYCLE OF TALKS IN DECEMBER RAISED THE URGENCY OF THE REUSE OF MINE TAILINGS

The topic that was addressed in the last CRHIAM Talk Cycle of 2022 was "Tailings and their relationship with water resources", which aimed to present the urgency of greener mining. The talk was given by Dr. Lina Uribe, CRHIAM associate researcher (Figure 83).

In this activity, Dr. Uribe spoke about tailings in mining, how they are formed, the importance of reducing pollution linked to them, the challenges and opportunities in mining, among other things. The analysis on tailings and water resources carried out by Dr. Lina Uribe addressed the reuse of this mining waste, the innovations in studies that have been carried out to carry out this work and the great challenge for this industry in reaching do not use continental water for your processes.

Figure 83. Talk "Tailings and their relationship with water resources".

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CENTRO DE RECURSOS HÍDRICOS PARA LA AGRICULTURA Y LA MINERÍA

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7 As a center we contribute to the public and private world

7.1 Contribution to public policies and meetings with private and public authorities

2022 CRHIAM POLICY BRIEFS

This year CRHIAM began the preparation of briefs to disseminate scientific evidence that contributes to public policies through the delivery of relevant and timely information. These documents address urgent national problems related to environmental matters and water resources and present recommendations for authorities with the aim of supporting decision-making based on scientific evidence. Below are the Policy Briefs published during 2022 (Figure 84).

Construcción de embalses para enfrentar la escasez hídrica

Autores: José Luis Arumí y Roberto Urrutia

Uso de la huella del agua para una gestión más sustentable de los recursos hídricos

Autores: Patricio Neumann y Gladys Vidal

La transición hacia una alimentación saludable
depende del incremento diferencial de la canasta de alimentos en el presupuesto familiar en los distitos quintiles

Autores: Stephanie Rivero Zambrano, Alex Godoy Faúndez y Diego Rivera Salazar

Gestión del agua en el marco de la seguridad hídrica: un problema de gobernanza

Autores: Ricardo Figueroa, Gladys Vidal y Roberto Ponce

Cosecha de aguas lluvias: incentivando a diversificar la matriz hídrica

Autores: Rodrigo Castillo, Felipe Barriga, Gloria Gómez, Ma. José Ortega, Amaya Alvez y Gladys Vidal

Recomendaciones para el uso sustentable del agua en la minería

Autores: Pedro G. Toledo y Leopoldo Gutiérrez

Figure 84. 2022 CRHIAM Policy Briefs.

CRHIAM DIRECTOR PARTICIPATED IN INAUGURAL ACTIVITY FOR THE CONFORMATION OF THE TABLE SCIENCE 2030 BIOBÍO-ÑUBLE

With the participation of nearly a hundred attendees, the Biobío-Ñuble Science 2030 Table was set up, which took place during the activity "Circular Economy: Creating synergies between academia, business and the public sector", an instance to the that the director of CRHIAM, Gladys Vidal, was invited, who highlighted the value of this type of economy to maintain products, components and materials at their maximum utility and value at all times, especially in the context of environmental climate emergency (Figure 85).

"This economy considers a paradigm shift between the current productivist and consumerist modes, which must face a transition from a linear economy ("take-manufacture-consume-eliminate") towards a more circular economy based on closed-cycle metabolic processes that be eco-efficient, rational and sustainable", said Dr. Vidal.

In this regard, he added that the circular economy is linked to the work of CRHIAM from the water cycle, since an important part of the research carried out at the center aims to understand and care for ecosystems from the perspective of water security, an international standard that It advocates guaranteeing water in quality and quantity.

The meeting was held in person and sought to be a space for connection, communication and joint work between the public, private and academic sectors. The study houses that group this table are the Universidad de Concepción (UdeC), Universidad Andrés Bello (UNAB), Universidad del Bío-Bío (UBB) and Universidad Católica de la Santísima Concepción (UCSC).

Figure 85. CRHIAM Director participating in the conformation of the Table Science 2030 Biobío-Ñuble.

CRHIAM RESEARCHERS LEAD SCIENCE AND TECHNOLOGY PROJECTS TO FACE DROUGHT

A total of 21 projects at the national level were selected for the Drought Strategic Research Fund, an extraordinary call for $6 billion to promote the development of R&D solutions to this emergency. Of these initiatives, CRHIAM researchers were awarded two proposals.

The first national place in this ANID contest is the project "CRHIAM technologies, methodologies and guide to good practices for water sustainability in the mining and agricultural industries", an initiative that is led by the main researcher CRHIAM, Dr. Leopoldo Gutiérrez and whose objective is to accelerate the availability of technologies, methodologies and protocols of best practices that have been generated in the CRHIAM center in the areas of mining and agriculture, to contribute with solutions to the problem of water scarcity in Chile.

The second project awarded by CRHIAM researchers was "Chileflux: Scientific network for monitoring water, energy and CO_2 flows as a tool for the control, adaptation and mitigation of climate change and drought in Chile", led by CRHIAM associate researcher Dr. Octavio Lagos.

The Strategic Drought Research Fund is part of the Government's Emergency Plan against Drought and seeks to increase the availability of water and improve the efficiency of its use through investment in infrastructure, promotion of irrigation and through regulatory measures. and management. Of the total applications received in this call, 55% of the projects were awarded, which will be developed within a year by centers and universities in regions, from Tarapacá to Aysén.

UNIVERSITIES OF CONCEPCIÓN AND ATACAMA CONCRETE ALLIANCE WITH GORE OF THE ATACAMA REGION TO PROMOTE SCIENTIFIC-TECHNICAL PROJECTS AND PROGRAMS

With the presence of university authorities from the UdeC, the University of Atacama and the GORE from this same region, a collaboration agreement was signed that will allow the design of a Regional Development Strategy (Figure 86).

The signing of the agreement took place after a trip by the university authorities to Copiapó on January 10, where the rectors Dr. Carlos Saavedra Rubilar, from the Universidad de Concepción and Celso Arias Mora, from the University of Atacama, were present, in addition to the Governor Regional Miguel Vargas Correa and the Vice Chancellor of Institutional Relations and Linkage with the Environment of the UdeC, Dr. Claudia Muñoz Tobar. Representing CRHIAM, the director, Dr. Gladys Vidal, attended.

This alliance will seek to promote the exchange of knowledge in science and technology, collaboration in medical specialties, and joint work around sustainable economic development, clean mining processes, regional studies, aquaculture and coastal development, territorial planning, social development and responsible water governance.

This strategic alliance agreement will have a duration of 5 years from the date of its subscription, and may be renewed automatically and successively.

Figure 86. Alliance between universities and Regional Government of Atacama Region.

CRHIAM PRESENTED POPULAR INITIATIVE ON WATER MANAGEMENT AND WATER SECURITY

The proposal, assigned as No. 47,538, seeks to discuss the governance of water resources, considering the human being, ecosystems and socioeconomic development (Figure 87).

The Water Research Center for Agriculture and Mining (CRHIAM) joined the Popular Initiatives for Standards promoted by the Constitutional Convention, through the proposal called "Governance and management of water within the framework of Water Security", in which raises the importance of looking in depth at this issue, considering climate change and the prolonged drought that affects the country.

This is an initiative that is based on scientific evidence compiled by the Center led by the Universidad de Concepción, in association with the U. de La Frontera and the U. del Desarrollo; and that reflects the interdisciplinary work of its researchers, who have extensive experience in water resources and knowledge of the different territories and basins of the country.

"As a Research Center of excellence, we have solid foundations to contribute to the constitutional discussion. A very important and priority issue is the management and good governance of water. Based on the scientific evidence we have; we believe that this form of management should aim to guarantee water security. This implies having water resources in quantity and quality so that our ecosystems are healthy, for human well-being and for socioeconomic development", says Dr. Gladys Vidal, CRHIAM Director.

The academic states that the proposal aims to generate a sustainable and balanced use of water and stresses that this must be done considering the needs of each of the basins. "Each territory of our country is very diverse; therefore, the management of water resources must be particular to each of these realities. The interesting thing here is being able to involve all the actors in order to collaborate and guarantee the quality and quantity of water over time for everyone", he assures.

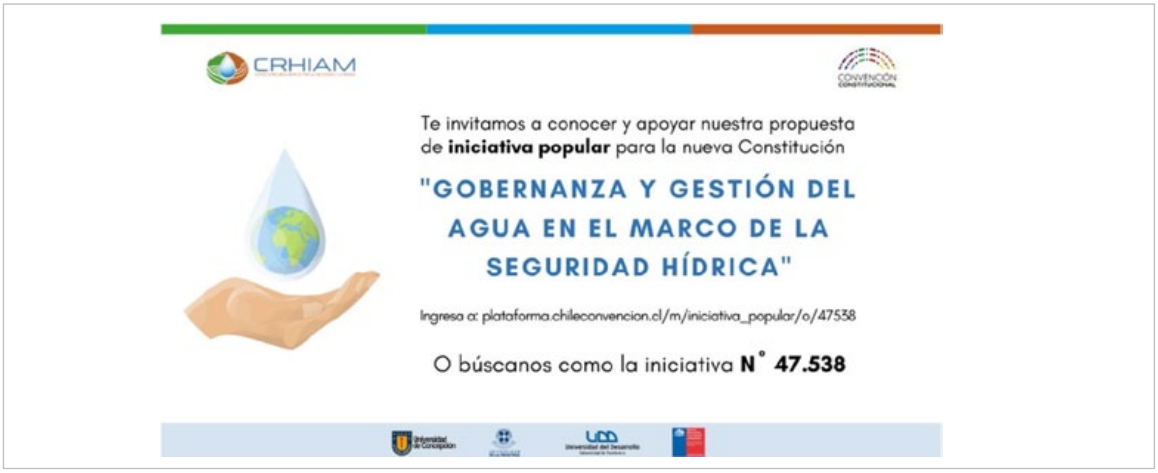

Figure 87. Popular initiative about water resources presented by CRHIAM to Constitutional Convention.

CRHIAM RESEARCHERS PRESENT AWARDED PROJECT ON GOOD PRACTICES FOR WATER SUSTAINABILITY TO THE MINISTRY OF AGRICULTURE

Within the framework of the "2021 Drought Strategic Research Fund", a meeting was held on January 25th between seven of the winning proposals of this fund and a team from the Ministry of Agriculture, led by the minister of the portfolio, Emilia Undurraga. On this occasion, the main researchers of each project briefly presented the objectives and results they hope to have with the execution of their respective initiatives.

From CRHIAM, the main researcher Dr. Leopoldo Gutiérrez, was in charge of presenting the project "CRHIAM technologies, methodologies and guide to good practices for water sustainability in the mining and agricultural industries", which aims to provide solutions to the water scarcity in Chile, with a focus on the technical, environmental, legal and social dimensions (Figure 88).

"We have a lot of information and research that we have developed in our Center, and we just need to put it on a platform that can serve the community. That is the general objective of this project, to accelerate the availability of these technologies, methodologies and protocols that have been developed in CRHIAM, both for mining and agricultural areas, but with a focus on different dimensions", explained Dr. Gutiérrez.

For her part, Minister Undurraga took advantage of the meeting to thank the researchers for making their proposals known. "I want to thank you for being part of this fund that the government has arranged in this broader framework of understanding drought not only as a specific problem and emergency, but rather as a structural change, and in this science, research and knowledge will be essential. And that knowledge must reach those who are actors in each of the territories," said the minister.

Figure 88. CRHIAM presenting awarded project on good practices for water sustainability to the Ministry of Agriculture.

CRHIAM RESEARCHERS MET WITH FUTURE MINISTER OF AGRICULTURE TO DISCUSS WATER CRISIS

To project future work focused on advancing towards sustainable agriculture and guaranteeing water security, the newly appointed Minister of Agriculture and academic at the University of Concepción, Esteban Valenzuela Van Treek, led a meeting with the UdeC Vice Chancellor, Carlos von Plessing Rossel, and researchers from the Center for Environmental Sciences (EULA-Chile) and the Center for Water Resources for Agriculture and Mining (CRHIAM) in the Rectory of the House of Studies (Figure 89).

On behalf of the Center, Dr. Pedro Toledo, deputy director of CRHIAM, participated. Meanwhile, the principal investigator, Dr. Ricardo Barra, who was representing the EULA-Chile Center, was also present at the meeting.

The future minister Valenzuela pointed out that the aim is to "advance to generate regional councils for water security and sustainable agriculture, such as collaborative watershed management, where the UdeC is key. In this sense, of course, I highlight the pioneering contribution of the EULA and the CRHIAM programs of applied science in several regions".

For his part, Dr. Pedro Toledo indicated that "he is a dialogue minister, I would dare to say that he has a reformist view regarding the management of water resources; wants to work in partnership with all sectors, academia, guilds, public and private, wants to build from trust. From CRHIAM in particular, he awaits the scientific evidence that will allow solving a significant number of problems associated with the use of water that have been diagnosed for a long time".

Figure 89. CRHIAM researchers met with future Minister of Agriculture.

CRHIAM PARTICIPATED IN THE SECOND NATIONAL MEETING OF HEADQUARTERS OF THE INFRASTRUCTURE AND TRANSPORTATION DIVISION OF REGIONAL GOVERNMENTS

In order to consolidate proposals that strengthen the decentralized development of the regions, representatives of the Infrastructure and Transportation divisions of regional governments from all over the country met on March 3th and 4th in Concepción with the aim of preparing a so-called "Act of Biobío de Infrastructure and Transportation Divisions.

The director of CRHIAM, Dr. Gladys Vidal, participated in this activity as a member of the Biobío Green Infrastructure Committee. "In the meeting we had the opportunity to dialogue with different actors, in particular I highlight the opportunity to share the scientific evidence carried out in CRHIAM with the Head of the Infrastructure and Transportation Division of the Regional Government of O'Higgins, Óscar Muñoz, with whom we seek spaces of joint cooperation" (Figure 90), said Dr. Vidal.

Both conferences were held at the Virginio Gómez Professional Institute, where topics such as bioregional projects, transfer of powers and concessions were presented. In addition, the event was attended by various authorities, such as the president of the Neuquén Provincial Government Investment Agency, José Brillo; the former head of the Department of Policies and Decentralization SUBDERE, Osvaldo Henríquez; the executive director of the Infrastructure Policy Council, Carlos Cruz; as well as the Rector of the University of Concepción, Dr. Carlos Saavedra, the Rector Virginio Gómez, Dr. Rolando Hernández.

It should be noted that the Green Infrastructure Committee is an advisory body that began its work in 2021. In particular, in the Biobío region, it seeks to review the critical areas that merit considering planning that includes climate change, to generate new ways of planning to mitigate and adapt the life of the population and the development of the region to this new climate scenario.

Figure 90. CRHIAM Director is member of the Biobío Green Infrastructure Committee.

CRHIAM MEMBERS MET WITH THE BIOBÍO ENVIRONMENTAL SEREMI

The director of the Fondap CRHIAM Center, Dr. Gladys Vidal, accompanied by the operations team, met on April 19th with the recently appointed Environmental Seremi of the Biobío region, Óscar Reicher, with the aim of showing the work and the initiatives that CRHIAM has led (Figure 91).

At the meeting, Dr. Vidal presented the lines of research of the Center, the main works that have been carried out in the field of water to respond to the water crisis that affects our country, and the communication initiatives that have been carried out to link with the private and public sectors and society in general.

This space made it possible to discuss the contribution that centers such as CRHIAM can make based on scientific evidence to contribute to better management of water resources, and to find points of common work to develop future projects.

Figure 91. Meeting between CRHIAM members and Environmental Seremi of the Biobío region.

CRHIAM RESEARCHER SPEAKS IN WEBINAR ON SECONDARY ENVIRONMENTAL QUALITY STANDARDS FOR NORTH-PATAGONIAN LAKES IN SOUTHERN CHILE

As an instance of early participation for citizens, a web seminar organized by the Ministry of the Environment (MMA) was held on April 27th, in which the advances in the preparation of Secondary Environmental Quality Standards for the North Patagonian Lakes of southern Chile.

This dissemination activity was attended by various guests, including Dr. Roberto Urrutia, CRHIAM principal researcher, who spoke about the "Collection, systematization and analysis of available information for the preparation of secondary environmental quality standards for the protection of the waters of the northern Patagonian lakes of Chile" (Figure 92), work entrusted by the MMA that will serve as input to support the process of preparing the standard.

The objective of the study is to discover the threats to the preservation of these lakes, their water quality, sediments and biota, possible impacts on aquatic ecosystems and the ecosystem functions and services associated with them. In addition, a conceptual model "Forcing-Pressures-State-Impacts-Responses" was designed for each of the 23 lakes studied.

Finally, the research proposes priority parameters to regulate in relation to the pressures identified and tables of quality classes for each of the prioritized parameters, either for each lake or a set of these.

Figure 92. CRHIAM Principal Researcher works to protect North-Patagonian lakes.

REGIONAL INNOVATION PROJECT SEEKS TO USE PULP EFFLUENTS FOR AGRICULTURAL IRRIGATION

Climate change and the mega-drought that affects a large part of the national territory, highlight the need for alternatives that optimize the consumption and use of water. In this context, the reuse of water makes it possible to take advantage of this resource more efficiently, although its treatment is key to this. This is precisely the objective of the FIC-R project "Use of cellulose effluents for agricultural irrigation", an initiative headed by the principal investigator of CRHIAM, Dr. Roberto Urrutia.

The project focuses on the reuse of wastewater from the pulp industry for small and medium-sized agriculture, reducing and eliminating remaining chemical elements or compounds that are not discarded in conventional treatment processes.

"The value of this project is that it allows us to be in contact with the community and contribute with solutions to one of the most serious problems that affects our region and a large part of the country, such as water scarcity. So that, with the experience of an interdisciplinary group of different researchers from the Faculty of Environmental Sciences, the EULA Center and CRHIAM, we can contribute to providing solutions through the reuse of effluents from the pulp industry for agricultural irrigation", explained the Dr. Urrutia.

"This initiative will contribute to the economic and social development of the Biobío region, more so in a sector that has growth potential and that generates great products that go for human consumption," added the Head of the Government's Development and Industry Division. Regional, Ivan Valenzuela.

The project began its execution in January 2022 and has a term of two years for its completion. It is financed by the Innovation Fund for Regional Competitiveness FIC-R, which in its latest version approved a total of 44 initiatives from the University of Concepción, and whose investment exceeds 13,400 million pesos for all of them.

CRHIAM DIRECTOR PARTICIPATED IN THE CONFORMATION OF THE GENDER TABLE OF CTCI OF BIOBÍO REGION

On July 21th, the Ministry of Science, Technology, Knowledge and Innovation held the formation of the CTCI Gender Table in the Biobío region, a meeting that included the participation of the Undersecretary of the portfolio, Carolina Gainz; the Regional Presidential Delegate of Biobío, Daniela Dresdner; and the Science Seremi of the South Central Macrozone, Sofía Valenzuela (Figure 93).

The activity brought together 25 women linked to science, among whom was the director of CRHIAM, Dr. Gladys Vidal. The participants met to learn about the ministry's guidelines on this matter, with the aim of reducing the gaps between men and women in the scientific area in the region, in addition to discussing the challenges in this area in the coming years.

This first meeting was held in person at the Emprendo UdeC building.

Figure 93. Formation of the CTCI Gender Table in the Biobío region.

PRINCIPAL RESEARCHER OF CRHIAM PRESENTED ON GROUNDWATER AT THE V INTERNATIONAL FORUM ON ENVIRONMENTAL JUSTICE

The V International Forum on Environmental Justice is an initiative devised and organized by the Second Environmental Court, with the aim of enriching the debate on environmental justice, both nationally and internationally.

CRHIAM's principal investigator, Dr. José Luis Arumí, participated in the 5th version of this forum, in which he spoke about groundwater, and the importance of knowing about this matter in order to alleviate the megadrought we are facing (Figure 94).

In this instance, he explained the relevance of the study of groundwater and soils, giving as an example the study of the Diguillín River and Renegado River basins, in the Ñuble Region, where the transfer of water occurs in its most of it is underground and does not come from a surface tributary.

This activity was carried out between Monday, November 14th and Tuesday, November 15th, in person in the North America room of the Intercontinental Hotel in Santiago and also remotely. It included prominent professionals from the world of justice and environmental law from countries such as Germany, Argentina, Brazil, Costa Rica, Hungary, India, El Salvador, Spain, the United States, France, Peru and Switzerland.

Figure 94. Dr. Arumí participated in the "V International Forum on Environmental Justice".

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8 Annexes

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Projects

FONDECYT Regular, code 1211738 (2021-2025). Enhancing pesticides degradation by microbial consortia acting on an efficient biopurification system enriched with biosurfactants. Responsible Researcher: Dr. María Cristina Diez.

FONDECYT Postdoctorate, code 3190918 (2019-2022) Biosurfactants produced by Antarctic bacteria in the degradation of chlorpyrifos by bacteria isolated from a biopurification system. Responsible Researcher: Dr. Claudio Lamilla. Sponsoring Researcher: Dr. María Cristina Diez.

FONDECYT Regular, code 1210964 (2021-2025). How the management of rhizosphere microbiota can enhance plant production under drought stress: Developing a scientific basis for the design of next generation biofertilizers. Responsible Researcher: Dr. Pablo Cornejo.

FONDECYT Postdoctorate, code 3210588 (2021-2024). Biofiltración de aguas salinizadas utilizando micorrizas arbusculares: creando bases científicas para la reutilización de aguas con fines agrícolas. Responsible Researcher: Gladys Vidal. Supervisor: Cristian Santander.

FONDECYT Regular, code 1191089 (2019-2023). Production of biogenic silver nanoparticles with antimicrobial activity in a fluidized bed reactor (FBR) coupled to a stirred tank reactor (STR) operated with immobilized fungal biomass. Responsible Researcher: Dr. Olga Rubilar.

FONDECYT Postdoctorate, code 3200963 (2020-2023). Formulation of a nanocomposite that allows the sustained release of copper nanoparticles and iprodione to be used against the phytopathogenic fungus Botrytis *cinérea.* Responsible Researcher: Dr. Javiera Parada. Sponsoring Researcher: Dr. Olga Rubilar.

FONDECYT Postdoctorate, code 3190922 (2019-2022). Pretreatment of lignocellulosic biomass by Fenton-like reaction (catalyzed by superparamagnetic Fe-NPs) combined with fungal MnP enzyme. Responsible Researcher: Dr. Edward Hermosilla. Sponsoring Researcher: Dr. Olga Rubilar.

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