CRHIAM

CENTRO DE RECURSOS HÍDRICOS PARA LA AGRICULTURA Y LA MINERÍA

ANID/FONDAP/15130015

2019

Annual Report CRHIAM

Universidad de Concepción

Universidad de Concepción

UNIVERSIDAD DE LA FRONTERA

Universidad del Desarrollo

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

CRHIAM
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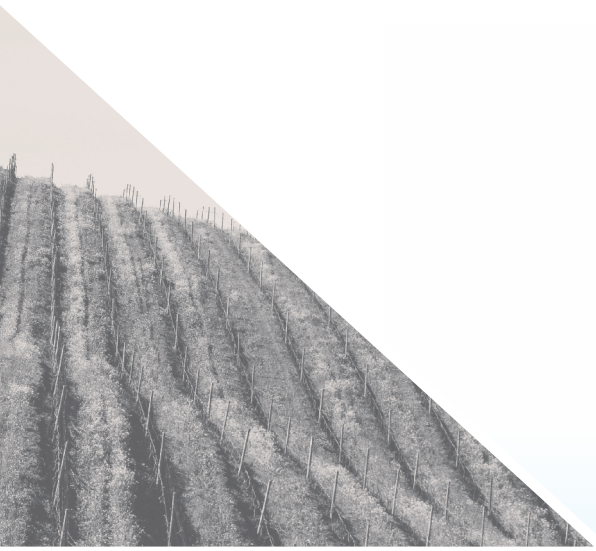

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AGRICULTURE

1. DIRECTOR'S MESSAGE

CRHIAM
CENTRO DE RECURSOS HÍDRICOS PARA LA AGRICULTURA Y LA MINERÍA
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In 2019, the second period of the Water Center for Agriculture and Mining (CRHIAM) began with the support of the FONDAP program for priority areas of ANID. CRHIAM was born to become a water management benchmark, generating advanced scientific and technological knowledge for the stable and harmonious development of agriculture, mining, and communities. Also, to interact with government institutions, local experts, and international organizations to influence the formulation of policies and the planning of more sustainable processes for the benefit of society.

During this second period, all researchers at the Center are working under the principle of Water Security, meaning "Capacity of a population to safeguard sustainable access to adequate amounts of water of acceptable quality for sustenance, well-being, and sustainable socio-economic development; guarantee protection against water-borne pollution and related disasters, and preserve ecosystems, in a climate of peace and political stability"

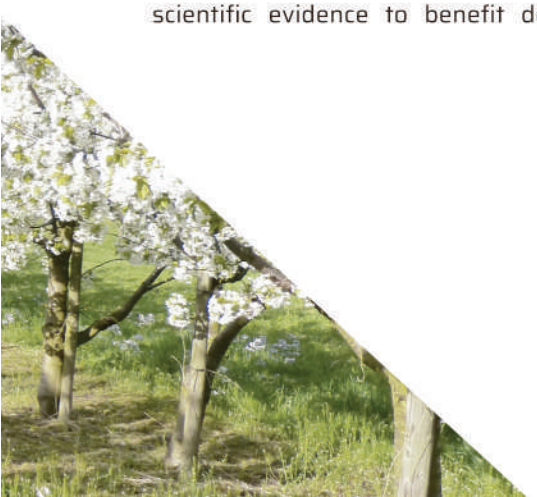
In 2019, the three original objectives of the Center were achieved, such as conducting research with national and international impact, training human capital at all levels, and generating effective national and international networks. A fourth objective was also strongly promoted to contribute to better water management through the communication and dissemination of scientific evidence that contributes to public policies and society's knowledge.

By this, work began on the publication of the "CRHIAM Communication Series" whose objective is to disseminate scientific evidence to benefit decision-makers, public policymakers, and society in general. On the other hand, dissemination and exploitation of the results were reinforced through cycles of monthly talks, seminars, summer courses, water forums, opinion columns in the written and digital press.

A significant milestone in 2019 was the start of the Diploma in Water Resources for Sustainable Development, aimed at professionals in the public, private, and academic fields. The first version had 17 students who graduated at the end of October 2019.

As a result of the performance in 2019, CRHIAM was evaluated as outstanding by the International Evaluation Panel.

The beginning of this second period of CRHIAM (2019-2023) has been very stimulating since the scientific evidence, and the dissemination and exploitation of results have been very well received by the stakeholders and social networks of CRHIAM. We appreciate all the support of the new Institutionality of the Chilean Research and Development Agency (ANID), and the constant support of the National Advisory Committee, the International Scientific Committee, and the international evaluators who have contributed with their suggestions to the continuous improvement of CRHIAM. We thank the authorities of the University of Concepción, through its Research and Development Vice-rector for their unconditional support, and the partner universities, Universidad de la Frontera and Universidad del Desarrollo. We especially thank the human group of CRHIAM, whose work has been fundamental to achieve success in the execution of this seventh year of life.



Dra. Gladys Vidal
Director

Dr. Pedro Toledo
Deputy Director

WATER

2. CRHIAM PROJECT

CRHIAM

CENTRO DE RECURSOS HÍDRICOS PARA LA AGRICULTURA Y LA MINERÍA

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Description

Chile is in the midst one of the most prolonged droughts in history. This water shortage affects the country's population, ecosystems, and economic development.

Agriculture and mining are two of the most important industrial activities in the national economy. Both activities face the difficult challenge of finding sustainability alternatives, even as the quantity of available water continues to decrease.

In 2014 the Water Research Center for Agriculture and Mining (CRHIAM) was founded under the framework of ANID's fifth Fund for Research Centers in Priority Areas (FONDAP) competition. The University of Concepción leads CRHIAM in association with the Universidad de La Frontera and Universidad del Desarrollo.

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, considering the principles of water security.

Objectives

CRHIAM has four main objectives:

- 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.
- Form undergraduate and especially graduate and postdoctoral human resources to create a critical mass that will support the development of abilities in the water resources field.
- Create networks with the main domestic and international research institutions and the public and private sectors to benefit from common interests regarding research, innovation and development in water resources.
- Contribute to better water management through communication and dissemination of scientific evidence that contributes to public policies and society´s kowledge.

Organizational Chart

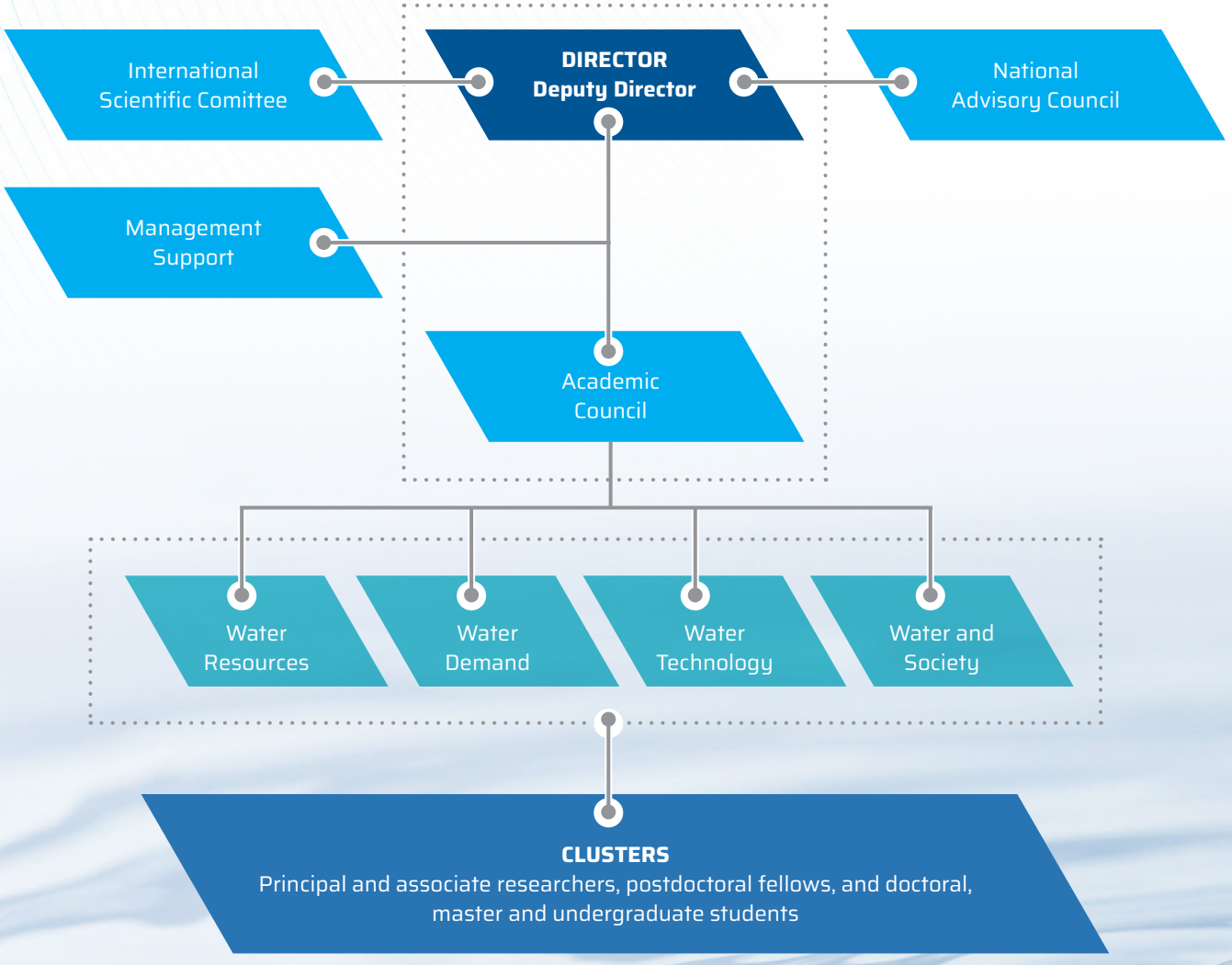

FIGURE 1.
CRHIAM Organizational Chart.

Team

The CRHIAM team is led by the administration and supported by administrative personnel. CRHIAM's management presents a hierarchy, as shown in Figure 2.

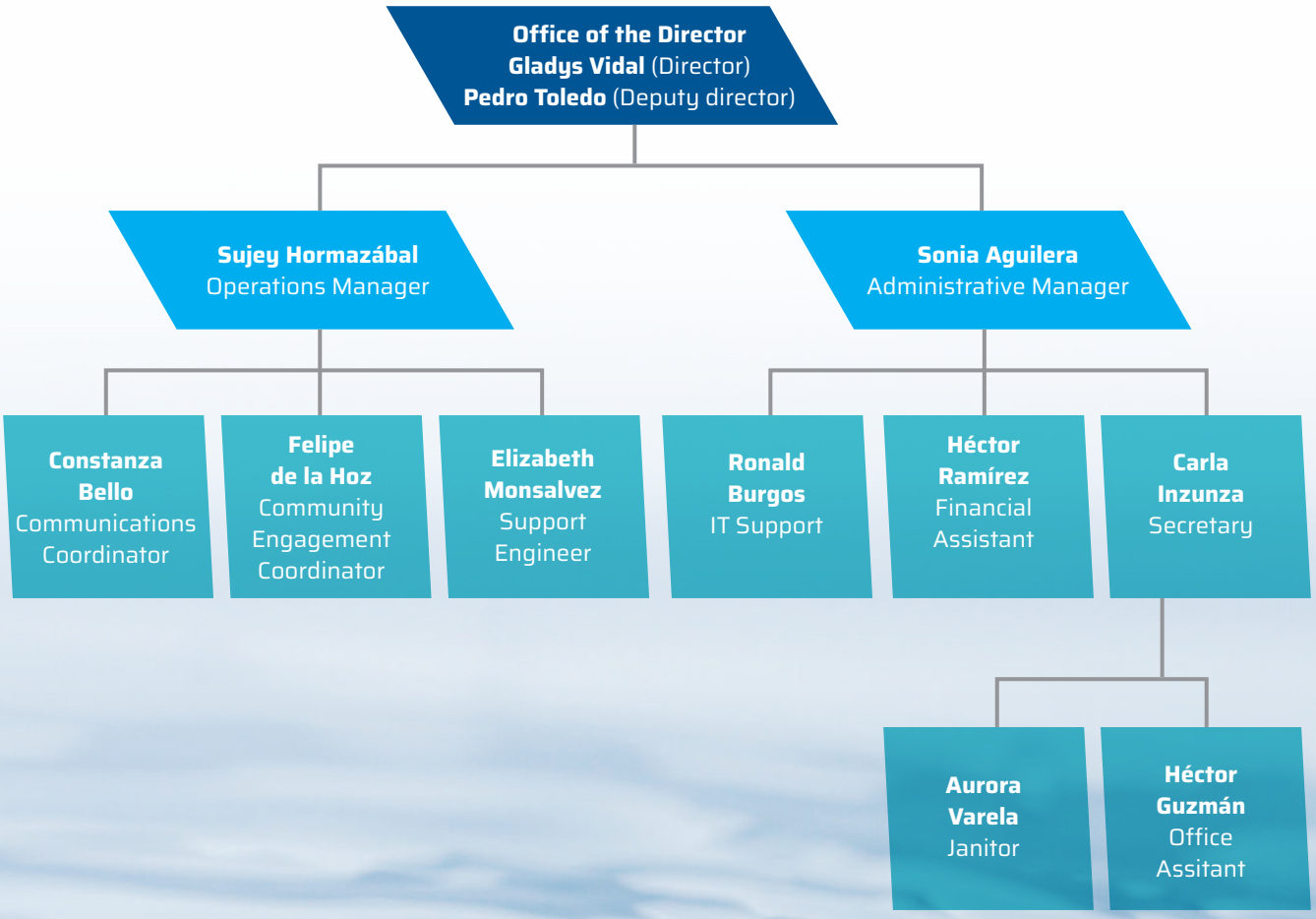

FIGURE 2.
CRHIAM Team Organizational Chart.

Scientific Committee

This committee is in charge of reviewing the fulfillment of commitments to ANID (ex Conicyt) in the ongoing project, recommending general and strategic guidelines, and suggesting new research lines or emphasizing current ones. This council is composed of five international experts in the center's disciplinary areas.

FIGURE 3.
Members of the Scientific Committee.

Advisory Board

This council verifies the fulfillment of the center's general goals. It connects CRHIAM to the community and recommends strategies for the center to connect its work with public sector institutions, government representatives, private sector organizations and society.

FIGURE 4A.
Members of the Advisory Board. First semester.

FIGURE 4B.
Members of the Advisory Board. Second semester.

Researchers

At CRHIAM, there are research staff in Chile and other parts of the world whom we call principal and associate investigators. These researchers analyze various issues related to the use and care of water resources for agriculture and mining. Its activities are carried out both the field and in the academia, providing the community with scientific and dissemination publications.

Academic Council & Principal Researchers

GLADYS VIDAL
(Director, Principal Researcher)

- **Cluster:** Water technology
- PhD in Chemical Sciences, Universidad de Santiago de Compostela.
- Industrial Engineering with a minor in Agroindustry, Universidad de la Frontera.

PEDRO TOLEDO
(Deputy Director, Principal Researcher)

- **Cluster:** Water resources
- PhD in Chemical Engineering University of Minnesota.
- Chemical Engineering, Universidad de Concepción.

DIEGO RIVERA
(Principal Researcher)

- **Cluster:** Water technology
- PhD in Agricultural Engineering, Universidad de Concepción.
- Civil Engineering, Universidad de Concepción.

MARÍA CRISTINA DIEZ
(Principal Researcher)

- **Cluster:** Water technology
- PhD in Food Sciences, Universidad Estatal de Campinas, SP, Brazil.
- Master of Food Science and Technology, Universidad Federal de Viçosa, MG, Brazil.

JOSÉ LUIS ARUMI
(Principal Researcher)

- **Cluster:** Water and society
- PhD in Engineering, University of Nebraska, Lincoln, USA.
- Civil Engineering, Universidad Técnica Federico Santaa María, Valparíso.

ROBERTO URRITIA
(Principal Researcher)

- **Cluster:** Water Resources
- PhD in Environmental Sciences, Universidad de Concepción.
- Biology, Universidad de Concepción.

FERNANDO CONCHA
(Principal Researcher)

- **Cluster:** Water demand
- PhD in Metallurgical Engineering, University of Minnesota.
- Chemical Engineering, Universidad de Concepción.

RICARDO BARRA
(Principal Researcher)

- **Cluster:** Water And society
- PhD in Environmental Sciences, Universidad de Concepción.
- Biochemistry, Universidad de Concepción.

Associate Researchers

ÁLEX GODOY
(Associate Researcher)

- **Cluster:** Water demand
- PhD in Engineering Sciences with a specialization in Chemistry and Bioprocesses, Pontificia Universidad Católica de Chile.
- Bioprocess Biology, Pontificia Universidad Católica de Chile.

AMAYA ALVEZ
(Associate Researcher)

- **Cluster:** Water and society
- PhD in Law York University, Canada.
- LLM in Law, University of Toronto, Canada.
- Law, Universidad de Concepción.

DAVID JEISON
(Associate Researcher)

- **Cluster:** Water technology
- PhD in Environmental Sciences, Wageningen University, Netherlands.
- Biochemical Engineering, Pontificia Universidad Católica de Valparaíso.

EDUARDO HOLZAPFEL
(Associate Researcher)

- **Cluster:** Water demand
- PhD in Water Resources Engineering, University of California.
- Agricultural Engineering, Universidad de Concepción.

JOSÉ LUIS CAMPOS
(Associate Researcher)

- **Cluster:** Water technology
- PhD in Chemical Sciences, Universidad de Santiago de Compostela.
- Chemical Sciences, Universidad de Santiago de Compostela.

FERNANDO BETANCOURT
(Associate Researcher)

- **Cluster:** Water demand
- PhD in Applied Sciences with a Specialization in Mathematical Engineering, Universidad de Concepción.
- Chemical Engineering, Universidad de Chile.

JORGE ROJAS
(Associate Researcher)

- **Cluster:** Water and society
- PhD in Sociology, University of Hannover, Germany.
- Master of Arts in Sociology and Political Science.
- Sociology, Institute of Sociology, University of Hannover, Germany.

LEOPOLDO GUTIÉRREZ
(Associate Researcher)

- **Cluster:** Water demand
- PhD in Mineral Processing, University of British Columbia.
- Master of Applied Science, Mineral Processing, University of British Columbia.
- Metallurgical Engineering, Universidad de Concepción.

MARIO LILLO
(Associate Researcher)

- **Cluster:** Water demand
- PhD in Computer Science, Universidad Politécnica de Madrid.
- Master of Engineering Sciences with a Specialization in Electrical Engineering, Universidad de Concepción.
- Electrical Engineering, Universidad de Concepción

OCTAVIO LAGOS
(Associate Researcher)

- **Cluster:** Water demand
- PhD in Engineering, University of Nebraska, Lincoln.
- Master of Agricultural Engineering with a Specialization in Water Resources, Universidad de Concepción.
- Agricultural Engineering, Universidad de Concepción.

OLGA RUBILAR
(Associate Researcher)

- **Cluster:** Water technology
- PhD in National Resource Sciences, Universidad de La Frontera.
- Environmental Engineering, Universidad de la Frontera.

PABLO CORNEJO O.
(Associate Researcher)

- **Cluster:** Water demand
- PhD in Agrarian Biology, University of Granada, Spain.
- Agricultural Engineering, Universidad de La Frontera, Chile.

PABLO CORNEJO R.
(Associate Researcher)

- **Cluster:** Water technology
- PhD in Agricultural Biology, Universidad de Granada, Spain.
- Agricultural Engineering, Universidad de la Frontera.

RAIMUND BÜRGER
(Associate Researcher)

- **Cluster:** Water demand
- Dr. rer. nat., Universität Stuttgart, Alemania.
- Diplon-Mathematiker, TU Darmstadt, Alemania.

RICARDO FIGUEROA
(Associate Researcher)

- **Cluster:** Water and Society
- PhD in Biological Sciences, Universidad de Málaga.
- Master of Sciences with a Specialization in Zoology, Universidad de Concepción.
- Biology Education, Universidad de Concepción

RICARDO OYARZÚN
(Associate Researcher)

- **Cluster:** Water resources
- PhD in Engineering Science, Washington State University.
- Master of Agricultural Engineering with a Specialization in Water Resources, Universidad de Concepción.
- Agriculture Engineering, Universidad de La Serena.

SERGIO ACUÑA
(Associate Researcher)

- **Cluster:** Water resources
- PhD in Engineering Sciences with a Specialization in Chemical Engineering, Universidad de Concepción.
- Food engineering, Universidad del Bío-Bío.

VERÓNICA DELGADO
(Associate Researcher)

- **Cluster:** Water and Society
- PhD in Law, Università degli Studi di Roma tor Vergata.
- Law, Universidad de Concepción.

Researchers

ÁLVARO TORRES

Universidad de La Frontera

PABLO SALGADO

Universidad de Concepción

DANIELA LÓPEZ

Universidad Adolfo Ibañez

PABLO PEDREROS

Universidad de Concepción

DANIEL VALENZUELA

Universidad de Concepción

GONZÁLO QUEZADA

Universidad de Concepción

CRISTOPHER RUYBAL

Universidad de Concepción

MARÍA ELIZA DÍAZ

Universidad de Concepción

VANESSA NOVOA

Universidad de Concepción

FELIPE TUCCA

Universidad Andrés Bello

CHRISTIAN SANTANDER

Universidad de La Frontera

MINING

3. 2019 ACHIEVEMENT SUMMARY

CRHIAM

CENTRO DE RECURSOS HÍDRICOS PARA LA AGRICULTURA Y LA MINERÍA

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Research

Figure 5 shows the CRHIAM performance during 2019 as compared to baselines set by FONDAP. The number of paper achieved was 40% higher than expected for this period. Moreover, the average impact factor achieved was 3.24; we expected 2.2. Also, 88% of the publications are in Q1/Q2 journal quartiles. On the other hand, advanced human capital training exceeded the predicted value as there are 18 postdoctoral researchers actively working. Several students graduated during 2019, that is, 13 PhD, 7 Master, and 31 professionals/ undergraduates (38 expected). Regarding "establishing collaborative network" and "dialogue, outreach and technology transfer" the effort in 2019 was to give greater visibility to the members of CRHIAM, their research and the contribution to public policies and society. The sections on "collaborative networks both at the national and international level", and "outreach to society" show the activities. In particular, the "dissemination and exploitation of results" shows this year´s strategy in five main points.

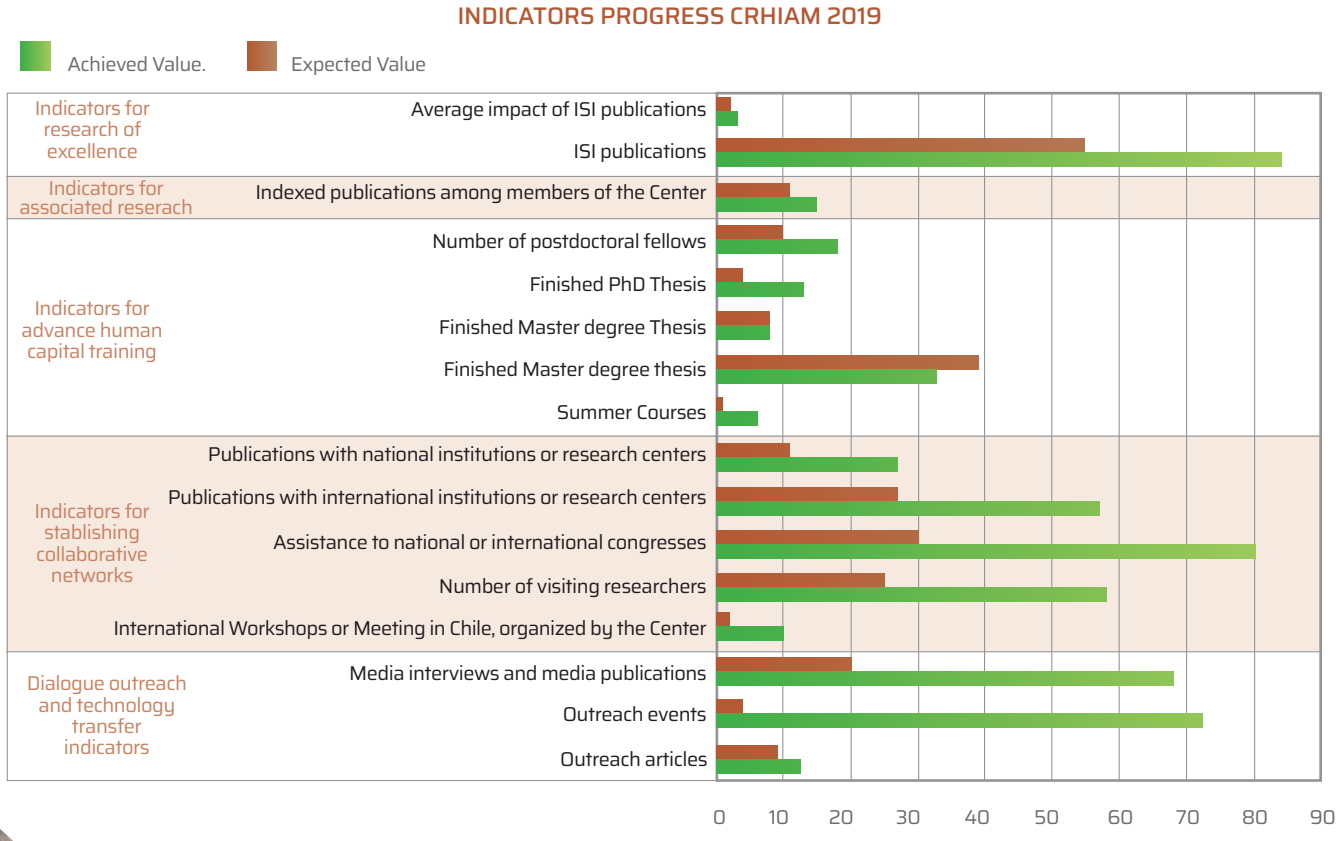


FIGURE 5.
Selected CRHIAM indicators of the sixth year of execution.

Since its creation, the Center has fostered collaboration among researchers to increase interdisciplinarity by providing cross-pollination spaces. To explain synergies and collaboration, we mapped co-authorship among researchers and extramural collaborators as networks. Each network's node represents a single researcher, while the thickness of each arc is proportional to the number of published papers, thus providing a proxy for the intensity of collaboration (the thicker the arch, the stronger the collaboration is). We used the network-approach to show how the Center has provided spaces to link disciplines. All data and graphs were created using CONICYT's public platform from https://dataciencia.conicyt.cl/red-coautoria/ using the names of all researchers. The network composed by the Center´s 32 researchers is shown in Figure 6, considering the productivity in the period 2014-2019. The number of published papers is 379, and the total number of coauthors is 1131. Considering that the number of links is 2089, each center's member generated, on average, 60 links. The graph is a compact and well-connected network, showing a strong collaboration among members, and other colleagues within the country (ca. 50 %) and abroad. In terms of multidisciplinary, research falls into multiple disciplines. Moreover, as a proxy for interdisciplinarity, the scientific outputs show a well-connected network, which indicates that most of the papers belong to two or more disciplines. The core disciplines are water resources, environmental sciences, chemistry and chemical engineering, crop and soil sciences, and geosciences. To illustrate how FONDAP funding has transformed the individual and collaborative research within the Center, we present two quantitative examples. The first example (Figures 6 and 7) shows the coauthorship network for a subset of 6 researchers working in agricultural water management (D Rivera, A Montecinos, O Lagos, A Godoy, M Lillo, E Holzapfel). By comparing the networks before and after year 2014 -when the center started- the group display a significant increase in the number of publications (29 to 61), number of total authors (95 to 179) and the number of links (155 to 278). Moreover, before 2014, there were three groups, two of which were weakly connected by two authors. The network currently shows a significant increase in the number of coauthored papers among members of the same group, which indicates strong collaboration. The second example (Figure 8) shows the co-authorship network for a subset of 7 researchers working in the Water & Society cluster (R Barra, JL Arumí, R Figueroa, A Alvez, V Delgado, J Rojas). This group started a completely new approach for water resources by combining a research group coming from law, engineering, biology and environmental sciences. Indeed, prior to 2014, both Principal Investigators were working separately, with sparse collaboration. Currently, the network shows a significant increase in the number of coauthored papers. This transformation occurred because both group leaders were able to strength disciplinary links and provide a conceptual framework -water security- that encompasses members' expertise. The group is also strongly connected with other groups within the Center, such as "water availability".

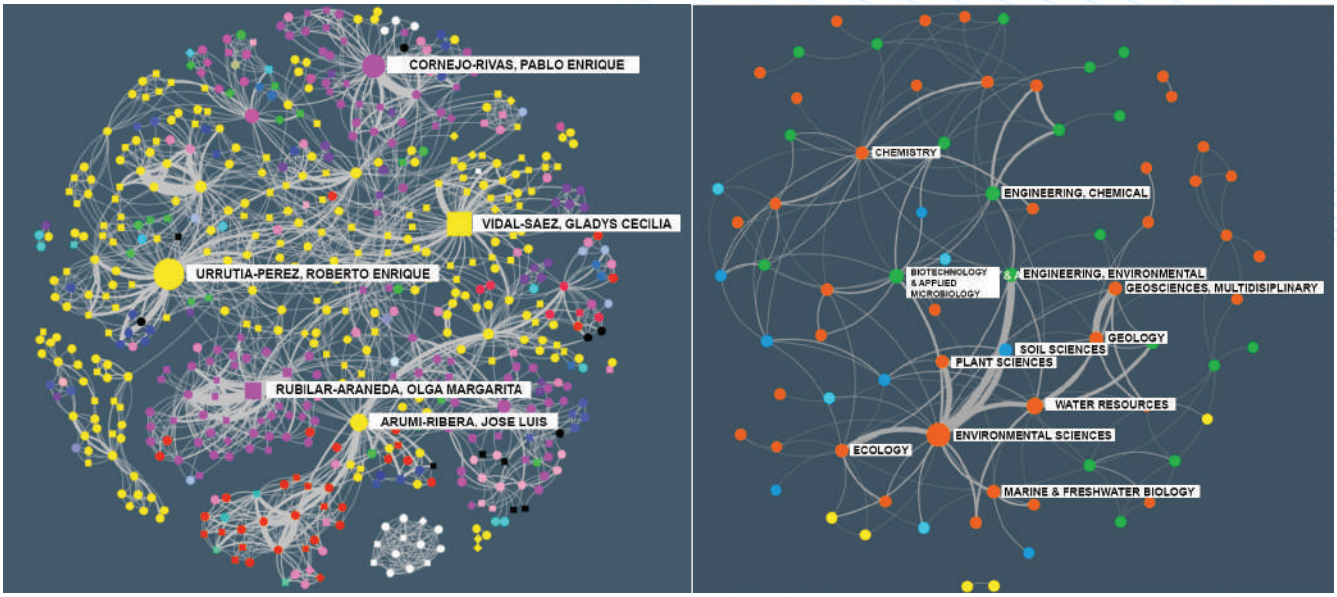


FIGURE 6.

Researchers´synergy from RL3, RL4, and RL5 (left) and between environmental engineering and environmental sciences, chemistry and chemical engineering, crop and soil sciences, biotechnology and applied microbiology, water resources, ecology and geosciences (right).

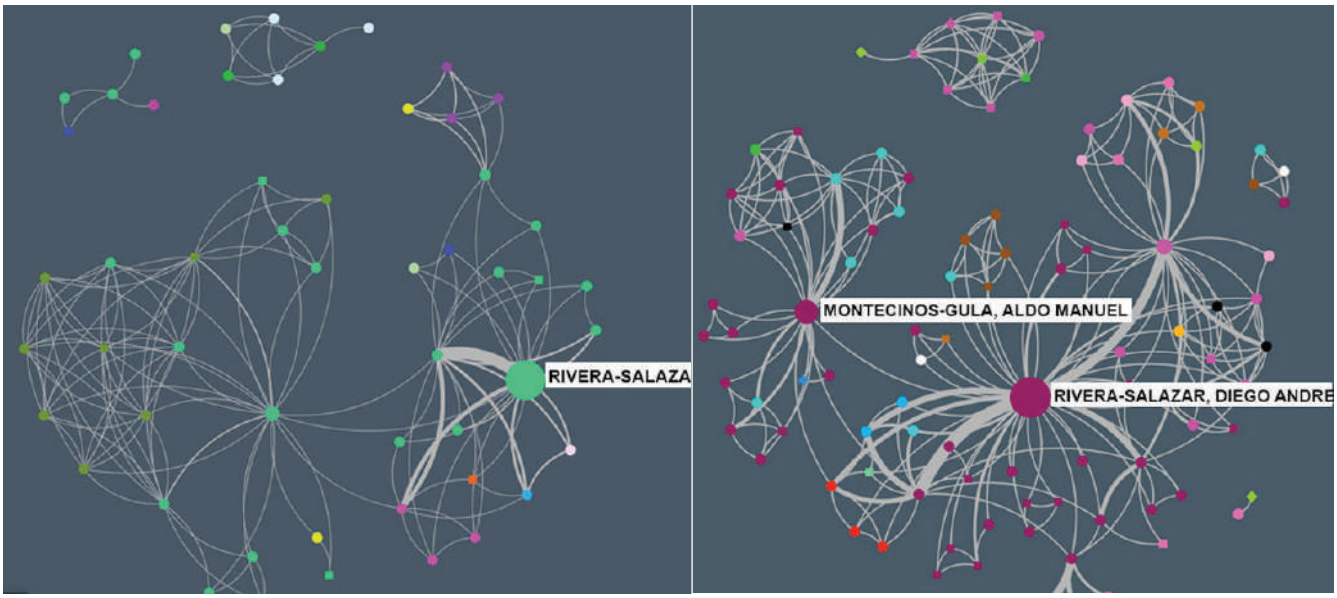


FIGURE 7.

Synergy growth through the project of the working cluster of Dr. Diego Rivera, (left) situation year 2014, (right) situation year 2019.

Overall, the Center has successfully provided spaces and resources to all researcher and group leaders to increase collaboration, scientific productivity and foster trans- and multidisciplinary. The reasons are strong leadership of Principal Researchers, regular discussion among members, and defining research questions that must be approached from different angles.

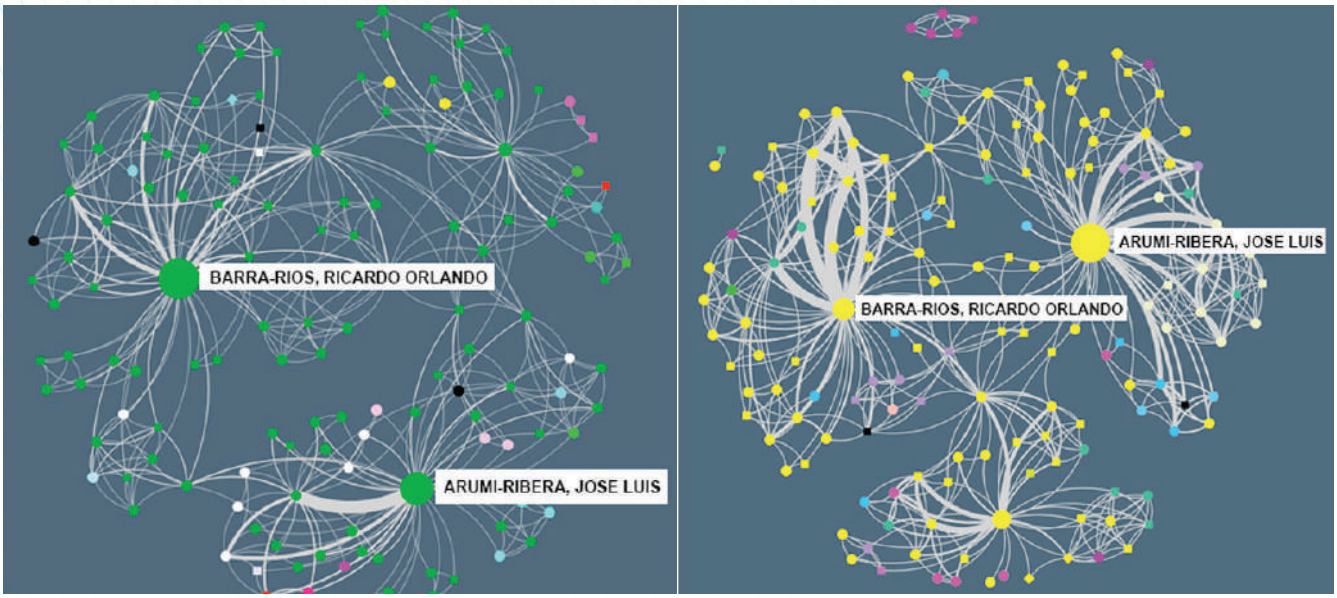


FIGURE 8.
Growth of the synergy of the water and society group. (left) Situation year 2014; (right) Situation year 2019.

The Center has sought to create networks with leading national and international research institutions in addition to the above networks. The data science platform is used to generate graphics of the institutional network associated with the Center. Given that each author has their affiliations associated, it is possible to transform authors´ network into the underlying Institutional network. Figure 9 shows the leading institutions associated with CRHIAM, among which the Universidad de Concepción and Universidad de La Frontera stand out.

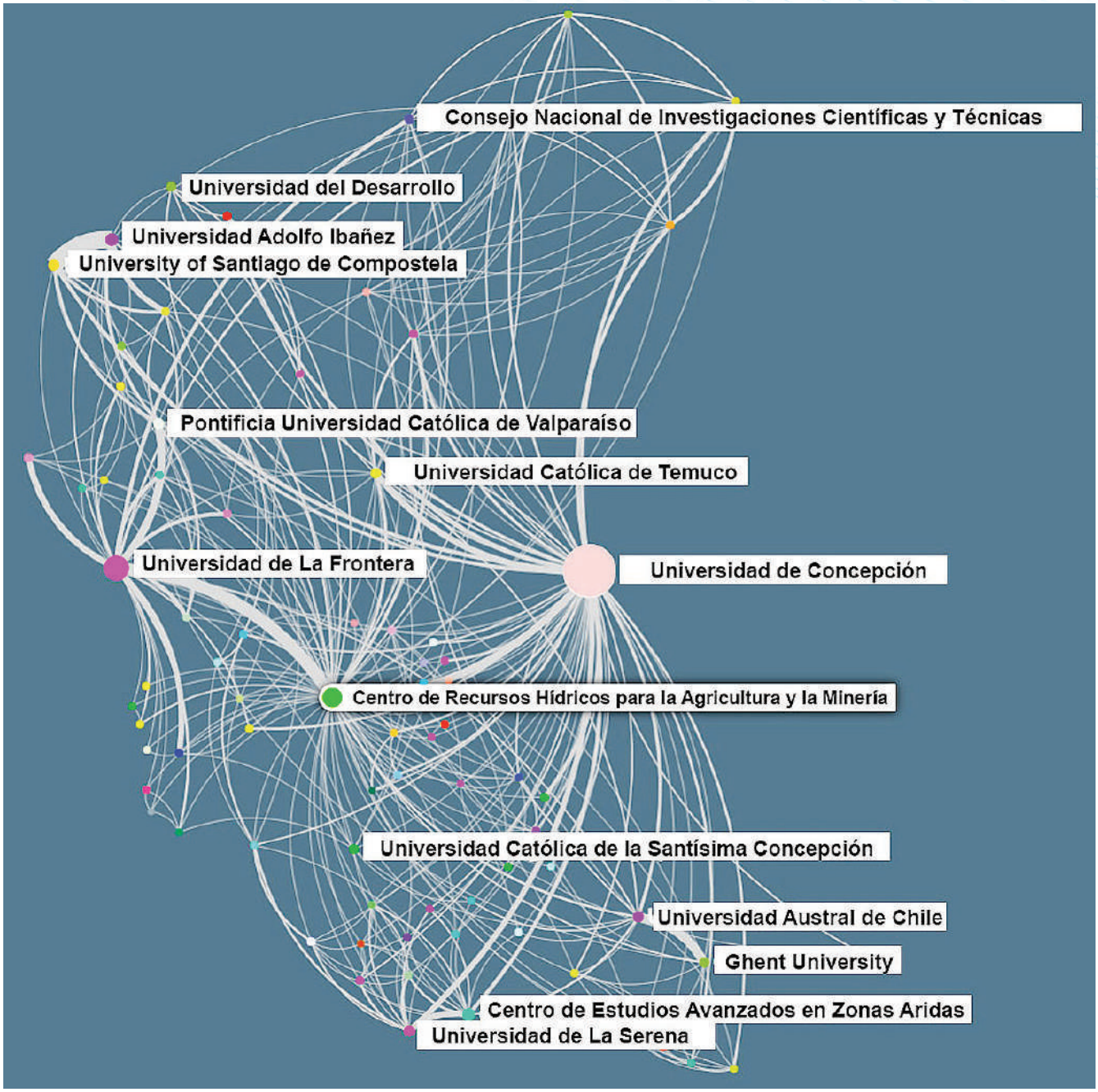


FIGURE 9.
CRHIAM Institutional Network.

Formation of Human Resources

CRHIAM actively participated in advanced human capital formation through doctoral programs in the center's national network of universities duly accredited by the CNA (National Accreditation Commission). Both principal investigators and associate researchers supervise students in doctoral programs, Environmental Sciences, Water Resources and Energy for Agriculture, Metallurgical Engineering, Engineering Sciences with a specialization in Chemical Engineering and Applied Sciences with a specialization in Mathematical Engineering, among others. Similarly, the center will participate in the training of master's students through the Master of Engineering Sciences with a concentration in Chemical Engineering, Master of Agricultural Engineering, and Master of Metallurgical Engineering, as well as undergraduate students by promoting the participation of young researchers that are active in CRHIAM's operations. Exchange agreements with foreign universities, particularly those associated with the center's international collaboration network, also were done. In particular, we exchanged Jose Luis Frontela from Universidad de Valladolid (Spain) and Levi Campos at the Queensland University (Australia). His stay is part of the master formation. Also, several undergraduate and postgraduate students went to different congress and meting supported by CRHIAM. During the year 2019, CRHIAM financed 3 postdoctoral 1-year fellowships and others 3 - 4 months fellowships, 4 postgraduates (2 masters and 2 doctorates), and 30 undergraduates fellowships. However, the total students who finished studies with this Researcher Center during 2019 were: 12 PhD., 7 masters, 31 undergraduate students, and 18 postdoctoral researchers. Figure 10 shows the total percentage of student undergraduate, master, doctorate, and postdoctoral researchers for 2019.

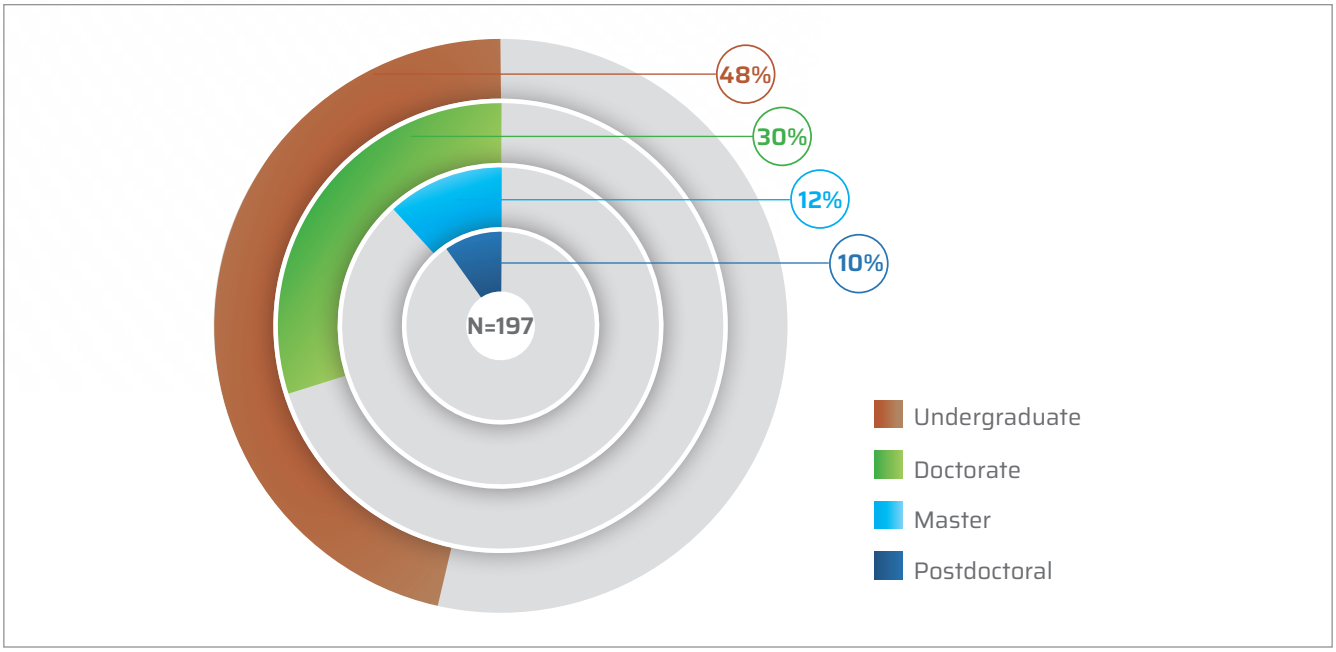


FIGURE 10.
Total percentage of students by academic grade in progress during the year 2019.

New activities to improve the internal communication of CRHIAM between students (undergraduate, postgraduate, master and doctorate, postdoctoral researchers), and researchers were made during 2019. For this purpose, the "First Students and Postdoctoral Researchers CRHIAM's Meeting" was held (April 10 and 17, 2019, at the Emprendo Auditorium of Universidad de Concepción). During the meeting, undergraduate students, master, doctorate, and postdoctoral researchers of CRHIAM presented the advances of their work, associated with the lines of research of the CRHIAM, in a congress format with a CRHIAM commission for oral or poster presentation. Figure 11 shows photographs of the students and researchers attending the meeting.

FIGURE 11.
First Students and Postdoctoral Researchers CRHIAM's Meeting.

Finally, this activity also left as a contribution to the dissemination of knowledge generated by each of the CRHIAM students and postdoctoral researchers through a book, which presents a summary and a graphical abstract of the work of each of the participants of the Meeting. Figure 12 shows the cover and back cover of the "First Students and Postdoctoral Researchers CRHIAM's Meeting" summary book.

FIGURE 12.
Cover (left) and back cover (right) of the Meeting summary book.

Fondap funding has been very relevant in supporting the training of students at different levels. The Postdoctoral fellow has been the key to connecting students who have completed their Ph. D., but they do not have an insertion in the working world. CRHIAM has offered one year of postdoctoral scholarship, which has served the for PhD researchers to potentiate their CV and then be incorporated in the academic staff and/or apply for the CONICYT postdoctoral fellowships. Under this example we have at CRHIAM during 2019 postdoctoral researchers with CONICYT fellow that previously they have been CRHIAM' fellow such as Drs. Daniela López, Pablo Salgado, Pablo Pedreros, and Felipe

Tucca, among others. Currently, Dr. Pablo Salgado applied to the call "Competition Grant for the Installation in the 2019 Academy of the Advanced Human Capital Attraction and Insertion Program, PAI" and now he is an Associate Professor at the Faculty of Engineering of Universidad Católica de la Santísima Concepción (Concepción). Under this same call, Dr. Carolina Reyes is an associated professor at the Universidad Bernardo O'Higgins; however, years ago, she was a postdoctoral fellow of CRHIAM. On the other hand, most undergraduate students work in the public sector, private sector, or start to study a postgraduate study.

Below is a list of scholarship students belonging to CRHIAM during the 2019 period in the different academic degrees, which include postdoctoral researchers, doctors, masters and undergraduate degrees.

TABLE 1.
CRHIAM 2019 Postdoctoral fellows.

NAME	RESEARCH TOPIC	TUTOR´S NAME	ASSOCIATED INSTITUTION
Gonzalo Quezada	Simulación de dinámica molecular de interfases mineral-agua en presencia de electrolitos y macromoléculas de reactivos: Mineral rico en litio (espodumeno) y relaves ricos en arcillas (caolinita y muscovite).	Pedro Toledo	Universidad de Concepción
Vanessa Novoa	Huella hídrica agrícola virtual para comprender el comercio del agua en Chile.	José Luis Arumí	Universidad de Concepción
María Elisa Díaz	Relevancia de los Servicios Ecosistémicos desde una Perspectiva Socio-Cultural como Fundamento para la Seguridad Hídrica.	Ricardo Figueroa	Universidad de Concepción
Christian Santander	Biofiltración de Aguas Sanilinizadas utilizando micorrizas arbsculares: Creando Raíces científicas para la reutilización de Aguas con fines Agrícolas	Pablo Cornejo Rivas	Universidad de La Frontera
Andrés Ramírez	Estudio de la Interacción de Dispersantes en el Sistema Molibdenita - Caolinita en Agua de Mar	Leopoldo Gutiérrez	Universidad de Concepción
Thais González	El rol de la microbiología en el sistema integrado humedal construido-celda de combustible microbiana en el tratamiento de las aguas servidas	Gladys Vidal	Universidad de Concepción

TABLE 2.
CRHIAM 2019 Doctorate student scholarships.

NAME	THESIS TITLE	TUTOR´S NAME	UNIVERSITY THAT GIVES THE DEGREE
Croswel Aguilar	Evaluación de los efectos del uso de efluentes de la industria de celulosa para riego.	Roberto Urrutia	Universidad de Concepción
Clara Tinoco	Manejo integrado de cuencas y fortalecimiento de capacidades de adaptación al cambio climático en las cuencas Biobío, Chile y Lerma-Chapala, México.	José Luis Arumí	Universidad de Concepción

TABLE 3.
CRHIAM 2019 Master student scholarships.

NAME	THESIS TITLE	TUTOR´S NAME	UNIVERSITY THAT GIVES THE DEGREE
Levi Campos	Valorización económica de las externalidades al agua y el aire en la minería chilena y australiana para el cálculo del PIV verde.	Fernando Concha	Universidad de Concepción
Daniela Rivera	Buscando la compatibilidad entre la protección ambiental y la actividad agrícola: el caso del sistema de las lagunas de Santa Elena	Jose Luis Arumí	Universidad de Concepción

TABLE 4.
CRHIAM 2019 Undergraduate student scholarships.

NAME	THESIS TITLE	TUTOR´S NAME	UNIVERSITY THAT GIVES THE DEGREE
Claudia Acuña	Debate jurisprudencial sobre la titularidad de Derechos de la Naturaleza: caso del Agua.	Amaya Alvez	Universidad de Concepción
Matías Aguirre	Caracterización espacio - temporal de la calidad de agua superficial y subterránea en la cuenca del Río Choapa	Ricardo Oyarzún	Universidad de La Serena
Nathalie de Brujin	Plantas desalinadoras por nanofiltración en la región del Biobío, desafíos y vacíos legales: perspectivas desde el derecho comparado.	Amaya Alvez	Universidad de Concepción
José Contreras	Eliminación de materia orgánica y nutrientes contenidos en aguas servidas de zonas rurales a través de sistemas de humedales construidos híbridos.	Gladys Vidal	Universidad de Concepción
Cristóbal Collins	Evaluación de la eficiencia de retención de fósforo en un humedal construido de flujo horizontal subsuperficial a escala piloto para el tratamiento de aguas servidas en zonas rurales.	Gladys Vidal	Universidad de Concepción
Nataly Díaz	Análisis de factores que determinan la explotación de aguas subterráneas en la cuenca del Estero Punitaqui.	Ricardo Oyarzún	Universidad de La Serena
Gabriela González	Conceptualización del sistema de aguas subterráneas del valle del Estero Renegado, Región de Ñuble, Chile.	José Luis Arumí	Universidad de Concepción
Agustín Maceratesi	Análisis crítico de los Bancos de Compensación en Biodiversidad como instrumento para combatir a la seguridad hídrica y al cumplimiento de los objetivos del Desarrollo Sostenible en Chile.	Verónica Delgado	Universidad de Concepción
Valeria Núñez	Análisis de procesos hidrogeológicos (cambios en el almacenamiento subterráneo) de la cabecera de las cuencas hidrográficas de la zona centro-norte de Chile.	Ricardo Oyarzún	Universidad de La Serena

NAME	THESIS TITLE	TUTOR´S NAME	UNIVERSITY THAT GIVES THE DEGREE
Luciano Quezada	Comparación de Riego por Goteo Superficial y Subsuperficial en Tomate Industrial con y sin nano-burbujas.	Eduardo Holzapfel	Universidad de Concepción
Loreto Sanhueza	Derecho Humanos al Agua y Saneamiento: de las normas a la realidad de los usuarios.	Amaya Alvez	Universidad de Concepción
César Vidal	Diseño y construcción de un ultraclasificador.	Fernando Concha	Universidad de Concepción
Eduardo Gómez	Propuesta de Abastecimiento de Agua Potable para las localidades rurales de la comuna de Santa Juana.	Roberto Urrutia	Universidad de Concepción
Camila Inzunza	Calidad del agua domiciliarios en la comuna de Coronel.	Ricardo Figueroa	Universidad de Concepción
Camila Palma	Calidad de las Aguas que se pueden recargar artificialmente en Chile a la luz del Derecho comparado.	Verónica Delgado	Universidad de Concepción
Ignacio Martínez	Uso de goma guar para mejorar recuperación de cobre en mineral con alto de arcillas en agua de mar.	Ricardo Jeldrés / Pedro Toledo	Universidad de Antofagasta
Catalina Beltrán	Enlazando los cursos de agua con la cultura y patrimonio de la comuna de Chillán Viejo.	José Luis Arumí	Universidad de Concepción
Lorenzo Cigarra	Estimación de la evapotranspiración instantánea en frutales mediante el modelo SEB-PV (The modified SEB model for Partially Vegetated surfaces) con imágenes aéreas y de satélite en Chile y California.	Octavio Lagos	Universidad de Concepción
Bárbara Muñoz	Calidad del agua en la cuenca del río Itata.	José Luis Arumí	Universidad de Concepción
Belén Cartes	Conflictos ambientales relacionados a la hidrogeología de humedales San Pedro-Coronel.	Ricardo Figueroa	Universidad de Concepción

NAME	THESIS TITLE	TUTOR´S NAME	UNIVERSITY THAT GIVES THE DEGREE
Bárbara Pérez	Recuperación de servicios ecosistémicos asociados a recursos hídricos con aguas claras de relave en la minería del cobre.	Roberto Urrutia	Universidad de Concepción
Felipe Vera	La contaminación difusa de las aguas en Chile. Desafíos para su regulación.	Verónica Delgado	Universidad de Concepción
Diego Quiñonez	Desarrollo de una metodología para apoyar la adaptación de organizaciones de agua potable rural al nuevo marco regulatorio de servicio sanitario rural.	José Luis Arumí	Universidad de Concepción
Trinidad Salas	Evaluación de reactivos hemicelulósicos en flotación de minerales arcilloso y su impacto en agua con Mg, Ca, Na, K.	Leopoldo Gutiérrez	Universidad de Concepción
Sebastián Segovia	Efecto de hemicelulosas en la flotación de minerales arcillosos en agua de mar.	Leopoldo Gutiérrez	Universidad de Concepción
Kevin Irribarra	Efecto de Silicatos de Sodio Modificados en la Flotación de Cobre - Molibdeno en agua de mar.	Leopoldo Gutiérrez	Universidad de Concepción

Finally, one of the important achievements of 2019 has been the “Water Resources for Sustainable Development” diploma given by CRHIAM. The Diploma was created to satisfy the country’s need for a more significant contingent of specialists in water resources, who have an updated and interdisciplinary view of the current situation concerning existing resources and biodiversity of ecosystems, demand, conflicts, and institutionalism. The program of the Diploma is structured in 4 modules (90 hours). Various aspects of water resource management will be discussed, in addition to some electives that will deepen issues of water importance (see Table 5).

TABLE 5.
Program of the Diploma "Water Resources for Sustainable Development".

MODULE	TEACHERS	HOURS
Module 1 Climate change, ecosystems and their effects on water resources. **Coordinator:** Dr. Roberto Urrutia	Dr. Alberto Araneda	4
	Dr. Roberto Urrutia	5
	Dr. José Luis Arumí	4
	Dr. Ricardo Figueroa	5
Module 2 Production processes, communities and water resources. **Coordinator:** Dr. Fernando Betancourt	Dr. Gladys Vidal	4
	Dr. Fernando Concha	
	Dr. Eduardo Holzapfel	5
	Dr. Diego Rivera	
	Dr. Fernando Beatancourt	4
	Dr. Pedro Toledo	
	Dr. Carolina Baeza	5
	Dr. Patricio Newmann	4
Module 3 Water technology for sustainability. **Coordinator:** Dr. Gladys Vidal	Dr. Gladys Vidal	5
	Dr. Patricia González	4
	Dr. Gladys Vidal	5
	Dr. Rodrigo Bórquez	4
Module 4 Conflicts over water, institutionality and instruments of water resources management in Chile. **Coordinator:** Dr. José Luis Arumí	Dr. Amaya Alvez	5
	Dr. Verónica Delgado	4
	Dr. Ricardo Barra	4
	Dr. José Luis Arumí	4
	Eng. Ovidio Melo	
	Dr. Jorge Rojas	3
Electives		12
TOTAL		**90**

In 2019 the first version of the diploma began; this program had 18 professionals from different areas and public, private and academic sectors, such as ESSBIO, DSS S.A. Consultant, BHP Minerals Americas, CAREP Ltda. Cooperativa, C&H Ltda. Security, Law Firm Mellibosky y Asociados and Universidad Católica del Maule. Figure 13 shows photographs of the students.

FIGURE 13 A.
Students generation 2019 diploma "Water Resources for Sustainable Development".





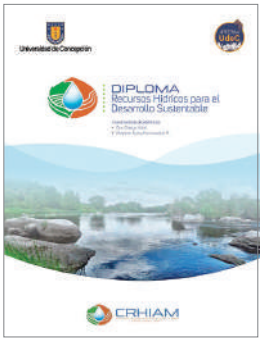



FIGURE 13 B.
Students generation 2019 diploma "Water Resources for Sustainable Development".

Table 6 details the profile of the 18 professionals from the first generation of students of the diploma.

TABLE 6.
Students generation 2019 diploma "Water Resources for Sustainable Development".

NAME	PROFESSION
Juan Arellano	Civil Engineer
Ignacio Bernard	Degree in Geology
Ma. Gabriela Chávez	Commercial Engineer
Carlos Gallardo	Mechanical Civil Engineer
Thiare Manríquez	Sociologist
Gianfranco Moris	Natural Resources Conservation Engineer
Magaly Muñoz	Degree in Biology and Agriculture Engineer
Álvaro Oñate	Civil Engineer
Carolina Pérez	Environmental Engineer
Danyelin Sanhueza	Geologist Civil Engineer
Ma. Fernanda Villalobos	Degree in Agronomy
Fabiola Norambuena	Engineering degree in Natural Resource Conservation
Marcos Zapata	Risk prevention Engineer
Juan Pablo Miranda	Environmental Engineer
Yenifer González	Environmental Engineer
Pía Escobar	Industrial Civil Engineer
Héctor Hernández	Lawyer
Leonardo Fernández	Physical Education Teacher

AGRICULTURE

4. DETAILED RESULTS (2019)

CRHIAM
CENTRO DE RECURSOS HÍDRICOS PARA LA AGRICULTURA Y LA MINERÍA
ANID/FONDAP/15130015

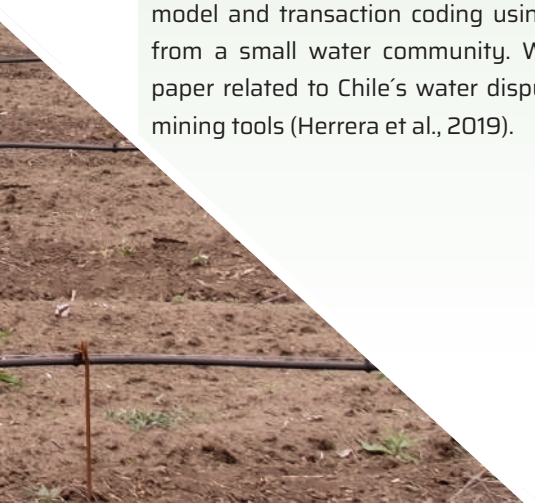
Research

RL1. Efficient use of water in agriculture and mining

We focused in a research program named "Towards water 4.0: Digitalization, automatization, and data science. The program aims to integrate information technologies – GIS, encryption, data science, automatization, decision support systems, and communication networks- into agricultural systems to support better water management for sustainable agriculture.

Management of water-related information: blockchain and smart contracts.

Chile's water regulation relies on the granting and allocation of water rights. However, the current registry system is incomplete, and it is not updated frequently. As the existing water rights database is asynchronous, there is no guarantee that transactions of water rights show legal security (who sells is the legal owner) or even physical security (who sells own enough water to make the transaction). Water users interact with each other in water markets on the bases of trust. Also, every transaction should be reported to different agencies, but current procedures are prone to errors. We have designed a platform for management and transaction of water rights within water user organizations that use blockchain and smart contracts technologies. This platform allows for transparency, accountability, traceability, and accessibility to information of water users, public agencies, and registry officials. As a case study, we developed a data model and transaction coding using real transaction data from a small water community. We have published one paper related to Chile´s water disputes with text and data mining tools (Herrera et al., 2019).



Risk analysis: using dry-spells modeling and climate modeling.

We use historical data (reanalyses and observations) to characterize dry spells over central and central-South Chile (30º to 40º S) from 1980-2015 and 2015-2040 regarding the extent, frequency, and persistence. We demonstrated the change in the frequency and length of dry spells that we hypothesize would have significate effects on public policy and tactical and strategic decisions in agriculture. We have tested a spatio-temporal pattern on the occurrence, extent and persistence of dry spells explained by climate variability. Changes In the persistence and occurrence of dry spells increase climate risks. Further results will provide a science-based appraisal of risks related to potential changes in crop spatial patterns and (water) infrastructure needs and policy. On the same line, we published 2 papers related to the Implications of climate change for semi-arid dualistic agriculture (Fernández et al., 2019) and precipitation interpolation to increase databases usability (Ossa-Moreno et al., 2019) that is an important input for modeling complex hydrological systems. We also validated a new method to obtain water from soil samples for isotopic analysis to explore the resilience mechanisms -water storage- in Andean watersheds that are suitable for application in agricultural systems to explore water plant use (Rivera et al., 2019).

H2Org:
An intelligent management tool for water allocation.

Information and Communication Technologies (ICTs) offers an opportunity to develop tools for the Water Users Association (WUA) to make decisions based on reliable, adequate, updated, and timely information from multiple sources and reduce the existing gap offer demand relationship for irrigation water. Thus, our objective is to design, develop, and implement a prototype Decision-Support-System (DSS) for WUA, using multiple sources of information, allows the management and planning of water distribution for irrigation. This objective considers the current context of high climatic variability and water scarcity, and the conditions of water demand, water rights, and hydraulic distribution systems. H2Org will allow: (i) to estimate the spatio-temporal water demand of crops present in the zone of influence of the WUA; (ii) systematic and automatically updated of agricultural land use cartography; (iii) estimate water availability taking into consideration the high climatic variability; (iv) to simulate different scenarios of crop patterns, irrigation systems and water availability, in order to evaluate the water offer-demand binomial. (v) to simulate scenarios that consider different objectives (e.g., strategic, social, economic, among others). We have published 5 papers related to remote sensing and artificial intelligence applied to agriculture for outlining agricultural fields (García-Pedrero et al., 2019a), image classification (Seal et al., 2019; García-Pedrero et al., 2019b), crop water use assessment (Gavilán et al., 2019), and methods to estimate crop evapotranspiration (Souto et al., 2019).

Irrigation management in apples and tomatoes:

The soil wetting pattern under drip irrigation is a relevant factor in apple tree production. It affects tree growth and development and the quality of fruits. We explored optimal wetting patterns in drip irrigation of apple (Gala Brookfield, M.9 dwarf rootstock) trees affected by soil type in two plots: El Manzano, clay loam irrigated three times per week; and Santa Mercedes, stony loam soil irrigated six times a week. There were significant differences in production and fruit quality ($p \leq 0.05$). The best results were obtained with one lateral per row (T1), two emitters per tree with discharge rates of 4.0 L h-1 in the clay-loam soil, and with four laterals per row (T3), eight emitters per tree and discharge rates of 1 L h-1 in stony loam soil. A manuscript is under preparation. An emerging technology today is the implementation of nano-bubbles or ultrafine bubbles. They have a greater capacity to transfer oxygen or gas to the water, and they also act as one of the most efficient disinfectants due to their electrical properties. We assessed the effect of nano-bubbles application in surface and subsurface drip irrigation for an industrial tomato orchard. Surface drip tape irrigation showed higher yields than subsurface irrigation. There were not significant differences in yield between treatment with and without nano-bubbles application. However, there was a higher weight of roots, with nano-bubbles. Finally, an excellent correlation was obtained between NDVI and the crop coefficients used. We are using an approach similar to Marino et al. (2019).

Flotation of copper minerals and by-products with seawater:

Seawater as process water for the mining industry has negative effects on the recovery of copper and sub products, due to the effect of the method used to eliminate undesirable contaminants. One of the most attractive alternatives from the metallurgical and economical point is the use of unprocessed seawater. This involves reagents that, during flotation, permit eliminating contaminants. During 2019 we studied: a) the effect of reagents, such as flocculant r, dispersants and hemicellulose, on the flotation of copper and molybdenite minerals; b) effect of microbubbles on the flotation of clay minerals; c) floating mechanism of enargite that can eliminate the arsenic contained in the copper concentrate; d) the effect of the degradation products of anionic anionic-polyacrylamide and their synergy with different metal ions on the floating molybdenite and chalcopyrite. Paredes et al. (2019); Gutiérrez et al. 2019, Gutiérrez, L. (2019), Ramírez et al. (2019); Patent No03817 granted to Gutiérrez-Universidad de Concepción. The use of seawater as Public Policy was also studied. (Alves et al., 2019).

Tailings in the mining industry:

One of the most serious operational and territorial problems of the copper mining industry is the generations of large amounts of waste material which in Chile totals 1.4 million tons per day and which must be discarded or confined somewhere to avoid environmental hazards. These tailings contain between 30 and 40% of water which is lost. Many of these tailings contain large amounts of fines and/or clays. (Jeldres et al., 2019) published a review on the effect of clays on the flotation of copper minerals. Ultra-flocculation hydraulic reactors were designed, built and validated (Del Río et al. 2019; Ruylov et al, 2019). A new Classification-Flocculation equipment was conceived and constructed which allows simultaneously the classification of tailings containing a large amount of fines, producing a coarse and dense material suitable for thickening and diluted flocculates fines also reporting to thickeners (Vidal, 2019, Concha et al., 2019). The classification stage of the tailings was studied with CFD and by experimentation in a pilot plant to develop a control system based on the vibrations produced in the equipment during its operation (Daza et al., submitted 2019). Evaporation in tailing dams (Céspedes et al. 2019) and the particle size distribution formed in tailing dams at a laboratory scale (Levi, 2019). A Patent was granted for an online rheometer; Patent No01274-2017 (Gutiérrez, 2019).

Mathematical Modeling, Optimization and Process Control:

The development of model process of the copper mining industry was essential to optimize and develop advanced control strategies. A well-controlled thickener can increase its production capacity by 5% and another 5% in water recovery. We have developed, based on three-phase water-gas-solid flow, a new mathematical model for the simulation of flotation columns (Bürger et al., 2019f) and a multilayer model of shallow water was formulated for polydisperse sedimentation in sedimentation tanks in agriculture (Bürger et al., 2019d). In addition, a mathematical numerical method was studied applied to double-diffusion problems in porous media with applications to water filters in lateritic areas. These advances have been accompanied with fundamental numerical schemes studies of degenerated-parabolic equations for and non-local and nonlinear problems, as well as WENO (Bürger y Kroker (2019). A model and its solution for batch sedimentation with coalescence were studied with applications to liquid-liquid phase separation (García and Betancourt 2019). A Dynamic Thickening Column was built and operated to test new control strategy, with a Dynamic Simulator (Pereira, 2019; Concha and Vergara, 2019; Concha et al., 2019).

RL2: New water sources for agriculture, mining and communities

Three major forces drive this line: (1) release fresh water for household and agriculture, (2) anticipate the policy of "not a single drop of fresh water should go to industrial processes", and (3) evaluate the use of low quality metallurgical water, seawater, well water and recycle water, to sustain or make viable the mining activity. This line closely follows the philosophy of Water Security whose seal we have committed to imprint on each CRHIAM activity. The mining industry continues to make great efforts to close the water cycle, however, the loss of water to tailings remains. The problem is further complicated by the presence of fine colloidal material that does not respond to traditional flocculants, this material is mainly made up of clays and its concentration increases in overexploited and low-grade deposits. From flotation, the single most important operation used for the recovery and upgrading of sulfides and nonsulfides, is based on properties of solid-liquid and air-liquid interfaces loaded with surface active agents, having molecular architectures of varying complexity. Over the years, abundant knowledge has accumulated from field and lab flotation of copper minerals in fresh water but not in saltwater. In recent times, flotation studies in saltwater have emerged but in general without properly addressing the molecular-scale mechanisms at the interfaces, which ultimately determine the effectiveness of the reagents. Little more than 70% of water is recycled in concentrators including a water make-up from tailings dams. Water recovery from decant ponds does not seem enough and thus the recovery of water from the porous medium formed by deposited tailings masses, unsaturated/saturated, begins to be necessary. This needs knowledge of multiphase flow in porous media that can be obtained for instance from oil recovery. Related to post-flotation wastes is society's claim about dam safety and chemical threat of its content. The lack of water and the perception of danger projected by dam tailings propel the striking idea of finding effective ways not involving water, as fluidization, to separate mineral particles. This is a precious goal underlying concepts of dry/green mining and mining without tailings. To advance, a math model is required that, unlike existing ones, can handle large volumes, typical of process equipment, here the ideas of astrophysical fluid

dynamics modeling are the inspiration. The knowledge on saltwater in copper mining is being transferred to the concentration of lithium from brines and rock ores. There is clearly an opportunity for the use of molecular simulation tools to optimize Li recovery. We anticipate that any knowledge about Li that can be generated here will be of great interest in producing countries such as Chile and in countries leading electromobility. The knowledge accumulated also provides an opportunity to help in the solution of problems even closer to society, such as the use of partially desalinated seawater in agriculture, the development of cost-effective methods to improve water quality for agriculture, and the use of clay particles to clean large bodies of water by flocculation of suspended colloidal matter. The objectives for 2019 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, and the use of molecular modeling tools implemented in high performance clusters and supercomputers and experimental procedures involving state of the art instruments and equipment. An account of the 2019 results per each CRHIAM major objective follows.

Modeling tools developed/finished in 2019:

Quantitative methodology based on molecular modeling tools (MMT) for the design of flotation, flocculation and anti-scale reagents. A network of 100 high-performance computers and the Southern GPU-cluster (SGPUC) is used to process codes in a parallel environment (Quezada et al., 2019a,b; Quezada and Toledo, 2019a). A code that allows counting adsorbed cations on a mineral surface and classify them according to number of contacts. This application (I-Complex) takes direct data from large commercial molecular simulators (Gromacs for example) (Quezada and Toledo, 2019b). We updated our saltwater flocculation model based on equations/ population balances (Quezada et al., 2019d). The model is an application in Matlab that to date we applied to flocculation of particle tailings at alkaline pH, that is to say in the presence of Mg hydroxides (PBM). We continued advancing in the modeling strategy based on coupled discrete element method and smoothed particle hydrodynamics for mineral processing in the absence of water (DEMSPH) (Achim et al., 2019a).

Applications developed in 2019 computer and experiment aided:

a) Applications of Molecular Modeling Tools (MMT and I-Complex) to water clarification and froth flotation, selection of reagents once surface mineral structure and cation adsorption densities are known, behavior of reagents in saltwater (Quezada et al., 2019a,b; Quezada and Toledo, 2019a,b); b) Applications of Population Balance Model (PBM) to water clarification, effects of agglomeration, breakage, geometry and permeability of flocs, flocculant aging, predictions to feed up control systems (Quezada et al., 2019d); c) Application of surface analysis tools to sulfide flotation with low quality water, upgrading surface mechanism in the presence of salts, passivation by coatings (Paredes et al., 2019a,b); d) Application of rheology to tailings particles transport to minimized water and energy uses (Saldaña et al., 2019; Cruz et al., 2019; Jeldres et al., 2019a,b,c; Robles et al., 2019); e) Applications of MD and Monte Carlo simulations to saturated and unsaturated flow in porous materials hopefully relevant to tailings masses (Toledo et al., 2019; Wagemann et al., 2019); f) Applications of coupled discrete element method and smoothed particle hydrodynamics for mineral processing in the absence of water (DEM-SPH) to particle fluidization and separation without water (Achim et al., 2019a,b,c,d); g) Application to improve water quality for agriculture in the south-central zones of Chile through cost-effective techniques, an interdisciplinary approach (García et al., 2019a,b,c).

Major Impact 2019:

Increase production of Li carbonate by improving Li-Mg separation; Improve performance of collectors in flotation stage of Li carbonate production; Unravel the true surface termination of Li-rich spodumene in saltwater; Design collectors for improving spodumene recovery in saltwater by MMT.

RL3: Availability and water quality for agriculture and mining under climate change

The year 2019 is ending with an important deficit of precipitations throughout the country that is stressing even more an already complicated situation due to the mega drought that has been affecting Chile since 2007.

Effect of climate change on water resources availability:

Most runoff entering river systems during the dry summer season is produce from melting of the snowpack and glaciers or from release of groundwater storage. We continue research to study the hydrological processes that control groundwater contribution to surface water bodies, at the watershed of Elqui, Limarí, Itata and Laja Rivers (Markovich et al., 2019; Oyarzún et al., 2019; Parra et al., 2019a,b)

- Development of monitoring and data analysis. We had been developing different applications of monitoring technologies in watersheds of central Chile, to combine the use of environmental tracers as isotopes, temperature and streamflow data to characterize the dynamic of the hydrological processes (Markovich et al., 2019). On this, the master thesis of Mr. Marcelo Diaz, developed a methodological approach to use photogrammetry and thermal imaginary to study a section of a river. As a new approach, we are developing the use of satellite-based sensors to study water resources in different watershed. The use of these tools is a very cost-effective alternative to time integrated water sampling for monitoring purposes (Cardenas-Soraca et al., 2019).

- Development of hydrogeological models for complex systems. We continued working on the improvement of hydrological models, focusing on the study of the water balance in the Laja and Diguillín watersheds, both located at the Biobio regions 37° S., at the foothills of the Andes Mountains. In spite that SWAT model has limitations in its applications in Andean watersheds with scarce soil data information, we were able, in collaboration with the Leibniz University of Hannover, to obtain good calibration of the model for the Laja and Itata Watersheds (Uniyal, 2019). However, we prefer the use of our own parsimonious models, which allowed us to study the effect of different management rules on the Laja Lake resilience (Muñoz et al., 2019). To improve the modeling of minimum stream flow, we develop methodologies for the use the available stream flow records to characterize groundwater storage and release systems (Parra et al., 2019a). We found that some model representation is better to others to characterize the recession flow of Chilean rivers (Parra et al., 2019b).

Evaluation of the impact of climate change on runoff generation in an Andean glacierfeed watershed:

The main objective of this study was to evaluate the impact of climate change on the generation of surface runoff in an Andean snow-glacier basin using the semi distributed hydrological model (Snowmelt Runoff Model) coupled with a glacier module in the Tinguiririca River Basin. The results of this research are part of the Master's thesis in Engineering Sciences of Rossana Escanilla, student of the Diego Portales University (finished in August 2019).

Glacier Mass Balance:

The melting of glaciers is also a driver of global sea level rise, which threatens densely inhabited coastal areas worldwide. Geometric changes of ice masses reflect the condition of a glacier with prolonged negative mass balance manifesting itself as frontal retreat and overall thinning, while advance of the front may be a symptom of mass gain or surging. Multi-temporal analyses, using Digital Elevation Model (DEMs) from different sources to estimates of ice mass state. In this context, a comparative analysis of glacier change was done using different DEMs for a case study on Universidad Glacier, an alpine valley glacier in the central Chilean Andes. The results of this research are presented in Podgorski et al. (2019).

Water quality in ecosystems affected by agriculture and mining:

- Rivers pollution. A Ph.D. thesis was conducted to assess the occurrence of pesticides in different environmental matrices (air, water, sediments) of the Cachapoal River Basin (Central Chile). The results of this research are presented in Climent et al. (2019a,b). Emerging threats to water quality in the Biobio River were observed by using semipermeable membrane devices SPMDs (a passive sampling device) and then assaying the extracts with a hormone binding receptor assay, the samples were taken downstream a pulp mill discharging their wastewaters in the river with a secondary treatment. The outcome is that the Biobio River contains unidentified chemicals that bind hormonal receptors that may cause endocrine disruption in organisms inhabiting the river (Orrego et al., 2019).

- Lake Eutrophication. We are working in lakes of South Central Chile (34-41° S) located in areas suffering changes in land usage from native forests to commercial trees plantation, together with an increase in agriculture, aquaculture, and urban areas (Troncoso et al., 2019), also in a number of lakes, with some becoming eutrophic (such as Lake Villarica) and increasing trophic levels in others, such as lakes Lo Galindo and Vichuquén (Pedreros et al., 2019). Both the pressures of climate change predicted for South-Central Chile and land use changes have increased the cyanobacterial blooms and modified the phytoplankton community of several lakes in Chile (Almanza et al., 2019).

New sources of water to meet future demand increases in agriculture and mining wastewater reuse:

- Artificial Groundwater recharge. The pressure associated with the drought and the uncertainty caused by climate change, has increased the dependency on the intensive use of groundwater. Due to this, we must advance in the development of artificial groundwater recharge technologies, which are not easy to implement and that require a lot of learning. It is necessary to understand how the recharge of groundwater occurs in a natural recharge to develop appropriate technologies according to the characteristics of the territory and of the organizations that manage such systems (Duhalde et al., 2019; Sandoval et al., 2019; Oyarzún et al., 2019).

RL4: Technology for water treatment and environmental remediation

The main forces drive this line of research in order to connect "water and environment" are: 1) An advanced membrane process for water treatment/reclamation, 2) Recovery of nutrients (P and N) for agriculture, 3) Use of agro-industrial wastes to develop substrates to improve the water-holding capacity in degraded areas for agriculture, 4) A biopurification system to prevent water and soil contamination and treat wastewater contaminated with pesticides and emerging contaminants, 5) Development of strategies using metallophytes and microorganisms to recover mining-polluted soil and water, 6) Recovery of water for mining and agriculture using biological and advanced nanotechnologies.

Advanced membrane process for water treatment/ reclamation:

Membrane processes have been traditionally considered as a feasible option for water reclamation or tertiary treatment. Microfiltration, ultrafiltration and reverse osmosis can be considered as standard operations nowadays. However, increasing attention is creating the application of membrane processes that are new to this application. During the reported period research was conducted on the combination of forward osmosis and membrane distillation, for the treatment of mining wastewaters (mine acid drainage). Studied configuration studied used membrane distillation as a way to re-concentrate draw solution used in the forward osmosis step, which is in contact with the mine wastewater. This creates a double membrane barrier that has the potential to securely retain heavy metals, providing an effluent of high quality. A manuscript is about to be submitted to publication containing results derived from this research.

Recovery of nutrients (P and N) for agriculture: Phosphorus recovery from the sludge line of WWTPs as struvite.

The main drawback to carry out struvite precipitation from anaerobic sludge digesters effluents is the high NaOH consumption needed to fit pH at a value of 8.5. This fact is due to the high buffer capacity of the anaerobic digester supernatant mainly caused by NH_3/NH_4^+ and $H_2CO_3/HCO_3^-/CO_3^{-2}$ equilibria. In this sense, the previous application of the nitrification or Partial Nitrification (PN)-Anammox processes could improve the economy of the phosphorus recovery since these processes consume both ammonia and alkalinity and, therefore, allow decreasing NaOH demand. As the effluent from the anaerobic sludge digester has a HCO_3^-/NH_4^+ ratio of 1 mol/mol, the available alkalinity only would allow removing 50% and of 89% of ammonia by means of nitrification and combination of PN-Anammox processes, respectively (Campos et al., 2019a) Therefore, after these treatments, enough ammonia would be still present to remove phosphorus as struvite. To achieve a stable partial nitrification process is the bottleneck to successfully apply PNAnammox processes. In the past, different authors proposed to operate the PN system under limiting oxygen conditions in order to promote nitrite accumulation. However, this strategy is not suitable since values of oxygen constant affinity of ammonia-oxidizing bacteria are higher than those of nitrite-oxidizing bacteria (Val del Río et al., 2019). Therefore, other strategies such as inhibition by free ammonia should be applied to obtain a stable PN process. On the other hand, N_2O, strong GHG, is produced as intermediate product during PN, this production being favored by nitrite presence (Campos et al., 2019b). In this sense, combination PN and Anammox processes in a single unit would allow converting ammonia into N_2 without accumulation of nitrite that would minimize N2O generation.

Use of agro-industrial wastes to develop substrates to improve the water-holding capacity in degraded areas for agricultural purposes:

- Green technologies for wastewater treatment in rural communities and reuse for local agriculture. Constructed wetlands (CW) meet these conditions and will be studied under various engineering configurations (surface-, horizontal subsurface- and vertical subsurface flow CW). Methane can be produced by biodegradation of organic matter under redox conditions (i.e. -350 mV) through horizontal subsurface constructed. The detection of methane production is by molecular characterization of bacterial and archaeal communities in a horizontal subsurface flow constructed wetland under cold and warm seasons (López et al., 2019a). On the other hand, it is not possible to eliminate total and fecal coliforms contained in sewage under the different designs of constructed wetlands (López et al., 2019b). Due to this, alternative disinfection technologies as ultrasound has been evaluated in to avoid secondary compounds due to the destruction of pathogen in the presence of recalcitrant organic matter (Vázquez-López et al., 2019). Effluent treated by the constructed wetland can be used in the reuse on agriculture sector. In order to ensure the quality of the effluent, phytoxicity can be an efficient tool for this porpoise (Leiva et al., 2019). New trends in sustainable water management are related to the use of resources contained in wastewater such as valuable nutrients, energy, water and chemical substances, with an approach to wastewater as a potential source of valuable resources rather than waste. In this context the technological possibility of microbial fuel cells, which directly convert waste into electricity or another chemical product with a high energy value, emerges. In a first approach, it was studied the effect of Zeolite-Fe on graphite anode in electroactive biofilm development for application in microbial fuel cells. This study show that the electrochemically active bacteria use acetate

as a substrate, which decreases the availability of the carbon source for archaea groups (methane-producing microorganisms) (González et al., 2019).

- Technology strategies for pesticides biodegradation. Pesticides in wastewater are characterized by high loads, high toxicity, low water solubility and serious problems of disposal and treatment. Pesticides can be degraded efficiently in biopurification system (BPS), but some of the metabolites formed during biodegradation could be more toxic and dangerous than the original compounds. The results of this study will help to improve current technologies for the biodegradation of these commonly used pesticides and will help to address the problem of pesticide contamination (Briceño et al., 2019, under evaluation).

The selection of the biomixture components for atrazine adsorption was first performed under batch conditions. This work demonstrates that atrazine treated in a column reactor packed with a low-cost biomixture is an efficient treatment for atrazine removal (Levio et al., 2019, submitted). Respect to pesticide-containing wastewater generated in agroindustry postharvest activities, like fruits processing or equipment washing, we evaluated encapsulated bacteria strains for degradation of a mixture of the pesticides atrazine, chlorpyrifos and iprodione in a continuous system. An adequate technology using encapsulated fungi with the ability to degrade pesticides at high concentrations avoid the risks of environment contamination by pesticides (Diez et al., 2019).

Recovery of water for mining and agriculture using biological and advanced nanotechnologies:

On the other hand, extensive use of pesticides and their accumulation in environment is a worldwide problem due to damage it can cause on human health, soils and not target plants. The use of adequate quantity and their removal is the great concern in the nowadays. In this sense, different technologies have been used, among them nanotechnology which has received great interest due to the high efficiency for attack of pathogens microorganism and too to the pollutant removal (Fincheira et al., 2019). In this context, studies developed by Manosalva et al. (2019) demonstrated that Galega officinalis extract using AgNO3 is possible synthetized silver nanoparticles with antimicrobial activity against Escherichia coli, Staphylococcus aureus and Pseudomonas syringae, being more effective than commercial pesticides (Herrera et al., 2019). In the same sense, today, metal nanoparticles could be in soil alter the sorption behavior of other contaminants such as pesticides (Tortella et al. 2019). Interestingly, at low organic matter, the pesticide sorption was notoriously increased in the presence of copper. However, NCu caused a minimal dose dependent effect compared with their bulk form. Conversely, at high organic matter, the sorption was slightly altered by the presence of NCu. These findings constitute the first evidence that copper nanoparticles applied to agricultural soils can modify the sorption behavior of fungicides, which might increase their permanence in the environment (Tortella et al., 2019). In addition, the atrazine adsorption is favored by the presence of NCu suggesting that NCu can increase the persistence of ATZ in soil, which may be mostly associated to physical-chemical interaction with soil particles more than a microbial impact (Parada et al., 2019). Also, nanotechnology is used as catalysts for chemical or photochemical oxidation produce the destruction of the recalcitrant compounds or fecal bacteria. Particularly, a new line of research using the green synthesis can be a solution sustainable for environmental pollutant by photocatalytic activity (Salgado et al., 2019).

Development of strategies using metallophytes and microorganisms to recover mining polluted soil and water:

Design of a siderophore productive platform for its use in agriculture. The genus Pseudomonas is characterized by the production of siderophores, iron chelating molecules that have the ability to nourish agricultural crops with iron. The use of these molecules is key to replace the application of EDTA and similar compounds, because they are questioned from an environmental point of view. The advantage of this strain is that it maintains a stable production of siderophore (specifically, pyoverdine) operating in nonsterile conditions. Tests have been carried out with several organic substrates to know which of them favored the production of siderophores, finding that acetate was the substrate that provided better results. Finally, tests were done to test the effect of the initial acetate concentration, with 1 g/L being the most favorable concentration.

- Improving arbuscular mycorrhizal fungal symbioses. Other important environmental constraints at the present is the water starvation, in the use of low-quality irrigation water, overuse of chemical fertilizers and the inclusion of soils with high concentrations of soluble cation, especially sodium (Na+). As noticeable results of our research emerges the beneficial effect of arbuscular mycorrhizal (AM) fungal symbioses in the roots of all the most representative plant species, being especially important in saline soils from Puna and PrePuna elevation belts in the Atacama desert (Santander et al., 2019a,b). In natural ecosystem of Araucaria araucana forests we also have demonstrated an important function of AM association improving the performance of Araucaria plants (Chávez et al., 2019). Also, preliminary results suggest that the AM fungi present in soils from Araucaria forest improve the growth of this plant species under drought stress conditions. Using Lactuca sativa plants we evidenced the contribution of the AM fungi to the plant tolerance against salt stress, which seems to be mainly produced through the modification of internal ionic ratios as the increase of K/Na ratio (Santander et al., 2019a). A most deep analysis allowed us to evidence the changes in plant physiology of lettuce mediated by AM fungi under salinity conditions (Santander et al. 2019b). However, new evidences obtained in this line also highlight the role of yeast and bacteria improving the tolerance to drought and other abiotic stresses, in such case based in the production of exopolysaccharides and displaying a series of plant-growth promoting traits (Silambarasan et al., 2019a-d).

RL5: Water governance, ecosystem services and sustainability

We carried out studies and analyses of existing public policies, regulations and institutional frameworks, obtaining relevant modalities and methods that will allow society to prosper by increasing human wellbeing, while conserving aquatic ecosystems, and make water available in quality and quantity suitable for various uses in the country within a participatory, transparent and democratic framework, while respecting fundamental rights, especially those of the most vulnerable groups, to water access. These conceptual frameworks are based on the idea that water should be managed as a common good, which entails management rooted in and aimed at the sustainable use of existing sources and potential new sources (seawater, storm water, gray water, etc.); to this end, it proves critical to significantly improve water protection while, at the same time, strengthening management through greater, more effective social participation in decision making. In terms of conflicts, we propose studying their profiles, dimensions and regional characteristics and completing assessments of water related trials in Chile, while also seeking to propose efficient modalities and opportunities for alternative conflict resolution, especially conflicts related to agricultural and mining production. Global climate change, which also affects Chile in terms of current and future water availability, will also be considered as a context for water security studies.

Ensure water quality and quantity from a fundamental rights perspective:

One of the baseline conditions of public policy is the existence of water related regulations that are consistent with the times and available scientific knowledge. To advance on that issue we had been developing research on several aspects that together allows us to improve our understanding of the relationship between society and water (quantity and quality).

Water footprint:

Understanding water consumption is crucial for sustainable management of water resources. We developed a research analyzing consume of water in central Chile based on the concept of water footprint, which separated the use of green, blue and gray footprint. The methodology was applied at the Cachapoal watershed, finding variability on the distribution of the water footprint depending of the hydrological year (Novoa et al., 2019a; Novoa et al., 2019b).

Desalination to address water scarcity:

At the crossroads: can desalination be a suitable public policy solution to address water scarcity in Chile's mining zones? One approach to alleviating scarcity is the incorporation of new water sources into supply systems, including desalinated seawater for industrial and municipal use. Alternative or complementary water supply options should be allowed where mining operations can demonstrate negligible hydrological and social impacts or use innovative solutions such as stakeholder water rights swaps and water efficiency technologies. We provide insight that help to drive a better policymaking process aimed at tackling water scarcity in Chile and in similar areas of the world.

Water quality of surface water bodies:

Due to the mega drought impacting central Chile, water quality seems to be impacted due to the lower water availability for dilution but keeping the same or even more intense agricultural and industrial use of water. To this end, work has been done since 2019 to improve the current regulation of a) secondary quality standards and decontamination plans (as Chile prepares its first water plan at Lake Villarrica); b) diffuse contamination (since there is no regulation) and c) in the improvement of emission standards (specifically with the MMA in the D.S. 46 that allows infiltrating the groundwater).

Groundwater management:

A database was constructed of all cases of crime of usurpation of water investigated in the Bio Bio region and it is concluded that there is little control and there is practically no conviction. The water code reform in 2019 was analyzed in an interdisciplinary manner, which improves control, imposes new sanctions on illegal extraction of groundwater, increases penalties for crimes and creates incentives for compliance with regulations (self-declaration). It is concluded that the reform has positive environmental aspects, but remains anchored in the protection of "water rights" and not in "water" as a common good; a book will be published on these topics in 2020. Another database was built, with all the failures of environmental damage to groundwater in Chile, to conclude that a) the main cause of the damage is Mining; b) that the damage is configured independently whether or not there is damage to the "rights" of water and; c) that the sentences to repair the damage only manage to cease the cause of the damage, but it is not condemned to restore the situation to the previous state (Delgado, 2019). In artificial groundwater recharge, our conclusion is that Chilean legislation is geared towards private use of their water rights to perform artificial groundwater recharge in order to generate a benefit to the private ones. So, we had been working with different government institutions to promote groundwater management based on Water Users Organizations (WOUs), a key stakeholder to address groundwater access at the territorial level. For the other hand, groundwater quality protection is not considered in our Law (Delgado et al., 2019, 2020), and there many cases where human activities could put in risk drinking water sources because of the lack of an adequate regulation (Arumí et al., 2019). Future research is oriented following this topic.

- Protection of different bodies of water and associated Ecosystem Services Understanding global ecological functionality and ecosystem services. Studies have been carried out on commitments and among the types of various ecosystem services associated with water resources, especially in the Biobío river basin, identifying the main drivers, identifying synergies where human activities e.g. renewable energy versus morphosedimentary regulation. Studies have also been carried out at the level of ecological functionality of intermittent rivers (global analysis) which may increase in number due to climate projections, among others: Sediment Respiration Pulses in Intermittent and Ephemeral Streams, Characterization of coarse particulate organic matter in intermittent rivers and Simulating flood pulse events in intermittent and ephemeral streams.

How to include environmental management at the Chilean Water Law?:

This year, 10 proposals were submitted for Chile's water law reform to advance in environmental protection considering the climate change variable (Delgado, 2019), accepted as definitive proposals at the Chilean Water Board to update the National Determined Contribution (NDC) to the UN convention of climate change. In addition, in the National Congress, it was presented a recommendation to the bill that proposes the integrated management of water resources in Chile.

Conservation instruments and territorial planning instruments:

This year, to protect springs, especially from illegal extraction in populated centers (case in the Renegade sector, the Andes in the Ñuble region), 4 ways of improvement were proposed: communal regulatory plans, regional land planning plans, construction permit control and subdivision permits of Dl 3516 (Arumi et al, 2019). In addition, it is in print a thesis book of the CRHIAM, where it is proposed that Chile advances in the principle "who conserves, charges" and legally consecrates instruments for environmental conservation. (Valdivia, 2020). In wetlands, Chile passed a law for "urban" wetlands (which is not yet effective). It was sponsored, within the UN COP 25 Oceans Bureau, that the NDC of Chile, include an international commitment to protect coastal wetlands (urban or not) for their role in the sequestration and mitigation of greenhouse gases (Farías, 2019).

Water governance:

- Water user's organizations. Using the contributions of the Theory of Common Assets of Elinor Oström, we examined the public good nature of waters in Chilean Law and their link to the notion of common goods. This public-common link implies critically revising water user institutions such as the River Surveillance Boards, their integration mechanisms, decision-making and socio-environmental responsibilities (Alvez et al., 2019). At the practical level, we had been actively working on the formation of the Itata and Biobío River Surveillances Boards, which are the first one that are being developed in rivers where irrigation is not the main User. This condition implies negotiations between users that allow to extend the current limitation of the Water Law.

- Water as a common good or decolonizing water law in Chile. Using the contributions of the Theory of Common Assets of Elinor Oström, we examine the public good nature of waters in Chilean Law and their link to the notion of common goods. This public-common link implies a critical revision of water user institutions such as the River Supervisory Boards, their integration mechanisms, decision-making and socio environmental responsibilities. When analyzing the normative configuration and some factual elements of the operation of the Supervisory Boards, contrasted with the principles of management of Common Goods proposed by Elinor Östrom, there is an important exclusion of agents that in fact are water users, especially non-extractive users, an unequal decision-making based on the amount of water shares of its owner (in many cases linked to its economic power) and lack of integrated planning at different levels, with binding instruments.

- Mediation in water conflicts. Water management models and utility of environmental mediation for cases of conflicts associated with water resources in Spain and Brazil, as well as their applicability in Chile are analyzed. In Chile, the management corresponds to the demand and the area with greater range of water resources available does not coincide with the densely populated areas and economic activity and does not consider hydrographic basins as territorial bases of the administration. Environmental Mediation is proposed

as an adequate strategy for the resolution of historical conflicts around the water management (Basualto et al., 2019).

- Social conflicts. Water conflicts are scaling up in Chile due to the impacts of both climate change/mega-drought, and several extractive activities such as agribusiness, forestry monoculture, among others. In response, communities and water social movements have been proposing alternatives to democratizing water governance at local and national scales. In order to afford these ongoing processes, on October 2019 we organized the X International Meeting WATERLAT-GOBACIT Chile 2019, which central theme was Struggles over Water: Intersections of Class, Gender and Ethnicity. Besides investigators from all Latin America and Chile, Mapuche people, women from "sacrifice zones", leaders from water social movements from Chile and abroad, water companies' unions, among other water actors, participated actively in the meeting. The central discussion was around how to struggle against injustice, inequality and defenselessness connected with water issues in terms of social class, gender and ethnicity, aiming to contribute to the construction of a more equitable and sustainable modes of water politics and management.

- Interdisciplinary contribution. A relevant contribution is also represented by the publication of the book "Water security: A view from the rights, scarcity, risks and citizen perceptions" (Rojas and Barra, 2019). It is the product of an interdisciplinary teamwork, and a CRHIAM view to contribute to the international debate. It reflects the concerns and studies carried out by researchers of the CRHIAM, interested in knowing the complexity of the water problem from an integrative perspective: it addresses the aspects indigenous people's rights to access to water, new efficient technologies, ecosystem services, legal and citizen perceptions, in the context of social, productive, institutional changes and of climate change and demands of citizens for access to water. All this falls under the concept of a democratic and inclusive water governance, that prioritizes human consumption.

- Contributions to public policy. CRHIAM researchers have been done work to detect the weaknesses of the wetland protection model and have participated by supporting the recent wetland protection law, which obliges activities that may affect it, undergoes environmental assessment processes. Our lawyers have participated in the opinion of experts before the Supreme Court, becoming the voice of these systems to claim their protection in exchange for the benefits they provide.

WATER
5. PUBLICATIONS

CRHIAM
CENTRO DE RECURSOS HÍDRICOS PARA LA AGRICULTURA Y LA MINERÍA
ANID/FONDAP/15130015

ISI Publications

- Arriagada, L., Rojas, O., Arumí, J.L., Munizaga, J., Rojas, C., Farías, L. and Vega, C. 2019. A new method to evaluate the vulnerability of watersheds facinhg several stressors: A case study in mediterranean Chile. Science of the Total Environment 651: 1517-1533.

- Novoa, V., Ahumada-Rudolph, R., Rojas, O., Munizaga, J., Sáez, K. and Arumí, J.L. 2019. Sustainability assessment of the agricultural water footprint in the Cachapoal River basin, Chile. Ecological Indicators 98: 19-28.

- Torregosa, M., Schwarz, A., Ñancucheo, I. and Balladares, E. 2019. Evaluation of the bio-protection mechanism in diffusive exchange permeable reactive barriers for the treatment of acid mine drainage. Science of the Total Environment 655: 374-383.

- Bürger, R. and Kroker, I. 2019. Computational uncertainty quantification for some strongly degenerate parabolic convection-diffusion equations. Journal of Computational and Applied Mathematics 348: 490-508.

- Bürger, R., Inzunza, D., Mulet, P. and Villada, L.M. 2019. Implicit-explicit schemes for nonlinear nonlocal equations with a gradient flow structure in one space dimension. Numerical Methods for Partial Differential Equations 35: 1008-1034.

- Del Río, M., Cornejo - Olivares, P., Betancourt, F., Concha, F. and Rulyov, N. 2019. Study of shear rate production in different geometric configurations of hydraulic reactors for ultra-flocculation. Chemical Engineering Research and Design 141: 133-143.

- Bürger, R., Chowell, G., Gavilán, E., Mulet, P. and Villada, L. 2019. Numerical solution of a spatio-temporal predator-prey model with infected prey. Mathematical Biosciences and Engineering 16(1): 438–473.

- Cornejo-D'Otonne, M., Figueroa, R. and Parra, O. 2019. Seasonality of the N2O cycle of the Biobío River during the megadrought. Journal of Limnology 78(1): 14-26.

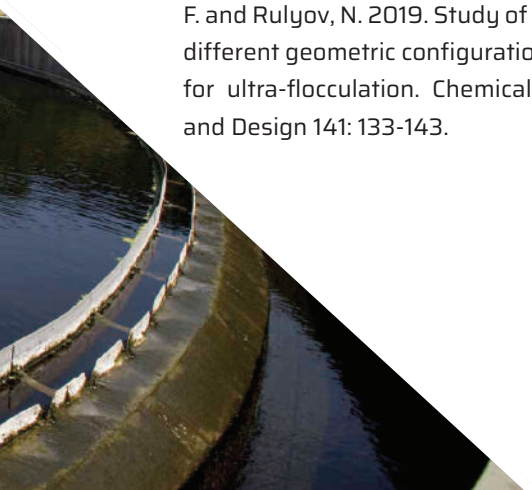
- González, T., Ureta-Zañartu, M.S., Marco, J.F. and Vidal, G. 2019. Effect of Zeolite-Fe on graphite anode in electroactive biofilm development for application in microbial fuel cells. Applied Surface Science 467: 851-859.

- Baeza, A., Bürger, R., Mulet, P and Zorío, D. 2019. Central WENO Schemes Through a Global Average Weight. Journal of Scientific Computing 78: 499-530.

- Rodríguez-López, L., Cárdenas, R., Parra, O., González-Rodríguez, L., Martin, O. and Urrutia, R. 2019. On the quantification of habitability: merging the astrobiological and ecological schools. International Journal of Astrobiology 18: 412-415.

- Val del Rio, A., Campos, J.L., Da Silva, C., Pedrouso, A. and Mosquera-Corral, A. 2019. Determination of the intrinsic kinetic parameters of ammonia-oxidizing and nitrite-oxidizing bacteria in granular and flocculent sludge. Separation and Purification Technology 213: 571–577.

- Jeldres, R., Uribe, L., Cisternas, L., Gutiérrez, L., Leiva, W. and Valenzuela, J. 2019. The effect of clay minerals on the process of flotation of copper ores - A critical review. Applied Clay Science 170: 57–69.



- Santander, C., Sanhueza, M, Olav, J., Borie, F., Valentine, A. and Cornejo Rivas, P. 2019. Arbuscular Mycorrhizal Colonization Promotes the Tolerance to Salt Stress in Lettuce Plants through an Efficient Modification of Ionic Balance. Journal of Soil Science and Plant Nutrition 19: 321-331.

- López, D., Leiva, A.M., Arismendi, W. and Vidal, G. 2019. Influence of design and operational parameters on the pathogens reduction in constructed wetland under the climate change scenario. Reviews in Environmental Science and Bio-Technology 18: 101-125.

- Oyarzún J., Nuñez, J., Fairley, J.P., Tapia, S., Álvarez, D., Maturana, H., Arumí, J.L., Aguirre, E., Carvajal, A. and Oyarzun, R. 2019. Groundwater Recharge Assessment in an Arid, Coastal, Middle Mountain Copper Mining District, Coquimbo Region, North-central Chile. Mine Water and the Environment 38(2): 226-242.

- Novoa, V., Ahumada-Rudolph, R., Rojas, O., Sáeze, K., De la Barrera, F. and Arumí, J.L. 2019. Understanding agricultural water footprint variability to improve water management in Chile. Science of the Total Environment 670: 188-199.

- Cuevas, J.G., Arumí, J.L. and Dorner, J. 2019. Assessing methods for the estimation of response times of stream discharge: the role of rainfall duration. Journal of Hydrology and Hydromechanics 67(2): 143-153.

- Cabrera, F., Torres, A., Campos, J.L. and Jeison, D. 2019. Effect of Operational Conditions on the Behaviour and Associated Costs of Mixed Microbial Cultures for PHA Production. Polymers 11(2): 191-204.

- Jeldres, R., Piceros, E.C., Leiva, W.H, Toledo, P.G., Quezada, G.R., Robles, PA. and Valenzuela, J. 2019. Analysis of silica pulp viscoelasticity in saline media: the effect of cation size. Minerals 9(4): 216-230.

- Herrera, M., Candia, C., Rivera, D., Aitken, D., Brieba, D., Boettiger, C., Donoso, G. and Godoy-Faúndez, A. 2019. Understanding water disputes in Chile with text and data mining tools. Water International 44(3): 302-320.

- Quezada, G., Rozas, R. and Toledo, P. 2019. Ab Initio Calculations of Partial Charges at Kaolinite Edge Sites and Molecular Dynamics Simulations of Cation Adsorption in Saline Solutions at and above the pH of Zero Charge. The Journal of Physical Chemistry C. 123: 22971-22980.

- Salgado, P., Márquez, K., Rubilar, O., Contreras, D., Vidal, G. 2019. The effect of phenolic compounds on the green synthesis of iron nanoparticles (FexOy-NPs) with photocatalytic activity. Applied Nanoscience 9: 371-385.

- Manosalva, N., Tortella, G., Diez, M.C., Schalchli, H., Seabra, A.B., Durán, N., Rubilar, O. 2019. Green synthesis of silver nanoparticles: effect of synthesis reaction parameters on the antimicrobial activity. World Journal of Microbiology and Biotechnology 35(6): 88-97.

- Tortella, G.T., Rubilar, O., Cea, M., Rodríguez-Rodríguez, C., Seguel, A. and Parada J. 2019. Sorption Parameters of carbendazim and iprodione in the presence of copper nanoparticles in two different soils. Journal of Soil Science and Plant Nutrition 19(3): 469-476.

- Bürger, R., Fernández-Nieto, E.D. and Osores, V.A. 2019. A dynamic multilayer shallow water model for polydisperse sedimentation. ESAIM-Mathematical Modelling and Numerical Analysis Modelisation Mathematique et Analyse Numerique 53(4): 1391-1432.

- Borie, F., Aguilera, P., Castillo, C., Valentine, A., Seguel, A., Barea, J.M. and Cornejo-Rivas, P. 2019. Revisiting the nature of phosphorus pools in Chilean volcanic soils as a basis for arbuscular mycorrhizal management in plant P acquisition. Journal of Soil Science and Plant Nutrition 19: 390-401.

- Cabrera, F., Serrano, A., Torres, A., Rodríguez-Gutiérrez, G., Jeison, D. and Fermoso, F. 2019. The accumulation of volatile fatty acids and phenols through a pH-controlled fermentation of olive mill solid waste. Science of the Total Environment 657: 1501-1507.

- Silambarasan, S., Logeswari, P., Cornejo Rivas, P., Abraham, J. and Valentine, A. 2019. Simultaneous mitigation of aluminum, salinity and drought stress in Lactuca sativa growth via formulated plant growth promoting Rhodotorula mucilaginosa CAM4. Ecotoxicology and Environmental Safety 180: 63-72.

- Bürger, R., Méndez, P.E. and Ruíz-Baier, R. 2019. On h(div)-conforming methods for double - diffusion equations in porous media. SIAM: Journal on Numerical Analysis 57(3): 1318-1343.

- Bürger, R., Inzunza, D., Mulet, P. and Villada, L.M. 2019. Implicit - Explicit methods for a class of nonlinear nonlocal gradient flow equations modelling collective behaviour. Applied Numerical Mathematics 144: 234 – 252.

- Bürger, R., Méndez, P.E. and Parés, C. 2019. On entropy stable schemes for degenerate parabolic multispecies kinematic flow models. Numerical Methods for Partial Differential Equiations 35(5): 1847-1872.

- López, D., Sepúlveda, M., Ruiz-Tagle, N., Sossa, K., Uggetti E. and Vidal, G. 2019. Potential methane production and molecular characterization of bacterial and archaeal communities in a horizontal subsurface flow constructed wetland under cold and warm seasons. Science of the Total Environment 648: 1042-1051.

- Reyes-Contreras, C., Leiva, A.M. and Vidal, G. 2019. Evaluation of triclosan toxic effects on methanogenic activity. Electronic Journal of Biotechnology 39: 61-66.

- Leiva, A.M., Albarrán, A., López, D. and Vidal, G. 2019. Evaluation of phytotoxicity of effluents from activated sludge and constructed wetland system for wastewater reuse. Water Science and Technology 79 (4): 656-667.

- Orrego, R. Mark Hewitt, L., McMaster, M., Chiang, G., Quiroz, M., Munkittricke, K., Gavilán, J.F. and Barra, R. 2019. Assessing wild fish exposure to ligands for sex steroid receptors from pulp and paper mill effluents in the Biobio River Basin, Central Chile. Ecotoxicology and Environmental Safety 171: 256–263.

- Climent, M.J., Coscollà, C., López, A., Barra, R. and Urrutia, R. 2019. Legacy and current-use pesticides (CUPs) in the atmosphere of a rural area in central Chile, using passive air samplers. Science of the Total Environment 662: 646–654.

- Bürger, R., Chowell, G. and Lara-Díaz, L. 2019. Comparative analysis of phenomenological growth models applied to epidemic outbreaks. Mathematical Biosciences and Engineering 16(5): 4250-4273.

- Baeza, A., Bürger, R., Mulet, P and Zorío, D. 2019. On the efficient computation of smoothness indicators for a class of WENO reconstructions. Journal of Scientific Computing 80(2): 1240–1263.

- Fernández, F. Blanco, M., Ponce, R., Vásquez-Lavín, F. and Roco, L. 2019. Implications of climate change for semi-arid dualistic agriculture: a case study in Central Chile. Regional Environmental Change 19: 89-100.

- Moernaut, J. Van Daele, M., Heirman, K., Wiemer, G., Molenaar, A., Vandorpe, T., Melnick, D., Hajdas, I., Pino, M., Urrutia, R. and De Batist, M. 2019. The subaqueous landslide cycle in south-central Chilean lakes: The role of tephra, slope gradient and repeated seismic shaking. Sedimentary Geology 381: 84–105.

- Podgórski, J., Kinnard, C., Pętlicki, M. and Urrutia, R. 2019. Performance Assessment of TanDEM-X DEM for Mountain Glacier Elevation Change Detection. Remote Sensing 11(2): 187-212.

- Troncoso, J.M., Vergara, C., Álvarez, D., Diaz, G, Fierro, P., Araneda, A., Torrejón, F., Rondanelli, M., Fagel, N. and Urrutia, R. 2019. A new multi-proxy record of environmental change over the last 1000 years on Chiloe Island: Lake Pastahue, south-central Chile (42 degrees S). Holocene 29(3): 421-431.

- Markovicha, K.H., Dahlkea, H.E., Arumí, J.L., Maxwell, R.M. and Fogga, G.E. 2019. Bayesian hydrograph separation in a minimally gauged alpine volcanic watershed in central Chile. Journal of Hydrology 575: 1288-1300.

- Shumilova, O., Zak, D., Datry, T., Von Schiller, D., Corti, R., Foulquier, A., Obrador, B., Tockner, K., Allan, D., Altermatt, F., Arce, M.I., Arnon, S., Banas, D., Banegas-Medina, A., Beller, E., Blanchette, M., Blanco-Libreros, J.F., Blessing, J., Gonçalves Boëchat, I., Boersma, K., Bogan, M., Bonada, N., Bond, N., Brintrup, K., Bruder, A., Burrows, R., Cancellario, T., Carlson, S., Cauvy-Fraunié, S., Cid, N., Danger, M., De Freitas Terra, B., De Girolamo, A.M., Del Campo, R., Dyer, F., Elosegi, A., Faye, E., Febria, C., Figueroa, R., Four, B., Gessner, M., Gnohossou, P.,Gómez Cerezo, R., Gomez-Gener, L., Graça, M., Guareschi, S., Gücker, B., Hwan, J., Kubheka, S., Langhans, S., Leigh, C., Little, Ch., Lorenz, S., Marshall, J., McIntosh, A., Mendoza-Lera, C., Irmgard Meyer, E., Miliša, M., Mlambo, M., Moleón, M., Negus, P., Niyogi, D., Papatheodoulou, A., Pardo, I., Paril, P., Pešić, V., Rodriguez-Lozano, P., Rolls, R., Sanchez-Montoya, M., Savić, A., Steward, A., Stubbington, R., Taleb, A., Vander Vorste, R., Waltham, N., Zoppini, A. and Zarfl, C. 2019. Simulating rewetting events in intermittent rivers and ephemeral streams: A global analysis of leached nutrients and organic matter. Global Change Biology Bioenergy 25(5): 1591-1611.

- Fuentealba, C.G., Rivera, R., Franco, C., Figueroa, R. and Faúndez, V. 2019. Patterns of richness of freshwater mollusks from Chile: predictions of its distribution based on null models. PeerJ 7: e7097.

- García, A. and Betancourt, F. 2019. Conservative Mathematical Model and Numerical Simulation of Batch Gravity Settling with Coalescence of Liquid-Liquid Dispersions. Chemical Engineering Science 207: 1214-1229.

- Parra, V., Arumí, J.L. and Muñoz, E. 2019. Identifying a suitable model for low-flow simulation in watersheds of south-central Chile: a study based on a sensitivity analysis. Water 11(7): 1506-1524.

- Paredes, A., Acuña, S., Gutiérrez, L. and Toledo, P. 2019. Zeta potential of pyrite particles in concentrated solutions of monovalent seawater electrolytes and amyl xanthate. Minerals 9(10): 584-595.

- Climent M.J., Herrero, E., Sánchez, M.J., Rodríguez, M.S., Pedreros, P. and Urrutia, R. 2019. Residues of pesticides and some metabolites in dissolved and particulate phase in surface stream water of Cachapoal River basin, central Chile. Environmental Pollution 251: 90-101.

- Muñoz, E., Guzmán, C., Medina, Y., Boll, J., Parra, V. and Arumí, J.L. 2019. An Adaptive Basin Management Rule to Improve Water Allocation Resilience under Climate Variability and Change—A Case Study in the Laja Lake Basin in Southern Chile. Water 11: 1733-1741.

- Souto, C., Lagos, O., Holzapfel, E., Lal Maskey, M., Wunderlich, L., Shapiro, K., Marino, G., Snyder, R. and Zaccaria, D. 2019. A modified Surface Energy Balance to Model Crop Transpiration and Soil Evaporation on Partially Wetted Orchard with Micro-irrigation Systems. Water 11: 1747-1773.

- Silambarasan, S., Logeswari, P., Cornejo-Rivas, P. and Rajesh Kannan, V. 2019. Role of plant growth-promoting rhizobacterial consortium in improving the Vigna radiata growth and alleviation of aluminum and drought stresses. Environmental Science and Pollution Research 26(27): 27647-27659.

- Souza Campos, P., Cornejo-Rivas, P., Rial, C., Borie, F., Varela, R., Seguel, A. and López-Ráez, J. 2019. Phosphate acquisition efficiency in wheat is related to root:shoot ratio, strigolactone levels, and PHO2 regulation. Journal of Experimental Botany 70(20): 5631-5642.

- Silambarasan, S., Logeswari, P., Valentine, A. and Cornejo-Rivas, P. 2019. Role of Curtobacterium herbarum strain CAH5 on aluminum bioaccumulation and enhancement of Lactuca sativa growth under aluminum and drought stresses. Ecotoxicology and Environmental Safety 183: 109573-109583.

- Urrutia, C., Yañez-Mansilla, E. and Jeison, D. 2019. Bioremoval of heavy metals from metal mine tailings water using microalgae biomass. Algal Research 43: 101659-101667.

- Fincheira, P., Rubilar, O., Espinoza, J., Añiñir W., Méndez, L., Quiroz, A. 2019. Formulation of a controlled-release delivery carrier for volatile organic compounds using multilayer O/W emulsions to plant growth. Colloids and Surfaces A: Physicochemical and Engineering Aspects 580: 123738-123749.

- Fincheira, P., Tortella, G., Durán, N., Seabra, A. and Rubilar, O. 2019. Current applications of nanotechnology to develop plant growth inducers agents as an innovation strategy. Critical Reviews in Biotechnology 40: 15-30.

- Almanza, V., Pedreros, P., Laughinghouse, H.D., Félez, J., Parra, O., Azócar, M. and Urrutia, R. 2019. Association between trophic state, watershed use, and blooms of cyanobacteria in south-central Chile. Limnologica 75: 30-41.

- Campos, J.L., Dumais, J., Pavissich, J.P., Franchi, O., Crutchik, D., Belmonte, M., Faúndez, M., Jorquera, L., Pedrouso, A., Mosquera-Corral, A. and Val del Río, A. 2019. Predicting Accumulation of Intermediate Compounds in Nitrification and Autotrophic Denitrification Processes: A Chemical Approach. BioMed Research International 2019: 2051986.

- Yepsen, R., Gutiérrez, L. and Laskowskic, J. 2019. Flotation behavior of enargite in the process of flotation using seawater. Minerals Engineering 142: 105897-105906.

- Bürger, R., Diehl, S. and Martí, M. 2019. A system of conservation laws with discontinuous flux modelling flotation with sedimentation. IMA Journal of Applied Mathematics 84: 930–973.

- Brintrup, K., Amigo, C., Fernández, J., Hernández, A., Pérez, F., Félez-Bernal, J., Butturini, A., Sáez-Carrillo, K., Yévenes, M. and Figueroa, R. 2019. Comparison of organic matter in intermittent and perennial rivers of Mediterranean Chile with the support of citizen science. Revista Chilena de Historia Natural 92: 3.

- Rivera, D., Gutiérrez, K., Valdivia-Cea, W., Zambrano-Bigiarini, M., Godoy-Faúndez, A., Álvez, A. and Farías, L. 2019. Validation of Cryogenic Vacuum Extraction of Pore Water from Volcanic Soils for Isotopic Analysis. Water 11: 2214–2225.

- Gavilán, V., Lillo-Saavedra, M., Holzapfel, E., Rivera, D. and García-Pedrero, A. 2019. Seasonal Crop Water Balance Using Harmonized Landsat-8 and Sentinel-2 Time Series Data. Water 11: 2236–2252.

- Seal, A., García-Pedrero, A., Bhattacharjee, D., Nasipuri, M., Lillo-Saavedra, M., Menasalvas, E. and Gonzalo-Martin, C. 2019. Multi-scale RoIs selection for classifying multi-spectral images. Multidimensional Systems and Signal Processing 745-769.

- Paredes, A., Acuña, S. and Toledo, P. 2019. AFM study of pyrite oxidation and xanthate adsorption in presence of seawater salts. Metals 9(11): 1177–1193.

- García-Pedrero, A., Lillo-Saavedra, M., Rodríguez-Esparragón, D. and Gonzalo-Martín, C. 2019. Deep Learning for Automatic Outlining Agricultural Parcels: Exploiting the and Parcel Identification System. IEEE Access 7: 158223-158236.

- Von Schiller, D., Datry, T., Corti, R., Foulquier, A., Tockner, K., Marcé, R., García- Baquero, G., Odriozola, I., Obrador, B., Elosegi, A., Mendoza- Lera, C., Gessner, M.O., Stubbington, R., Albariño, R., Allen, D.C., Altermatt, F., Arce, M.I., Arnon, S., Banas, D., Banegas- Medina, A., Beller, E., Blanchette, M.L., Blanco- Libreros, J.F., Blessing, J., Boëchat, I.G., Boersma, K.S., Bogan, M.T., Bonada, N., Bond, N.R., Brintrup, K., Bruder, A., Burrows, R.M., Cancellario, T., Carlson, S.M., Cauvy- Fraunié, S., Cid, N., Danger, M., de Freitas Terra, B., Dehedin, A., De Girolamo, A.M., del Campo, R., Díaz- Villanueva, V., Duerdoth, C.P., Dyer, F., Faye, E., Febria, C., Figueroa, R., Four, B., Gafny, S., Gómez, R., Gómez- Gener, L., Graça, M.A.S., Guareschi, S., Gücker, B., Hoppeler, F., Hwan, J.L, Kubheka, S., Laini, A., Langhans, S.D., Leigh, C., Little, C.J., Lorenz, S., Marshall, J., Martín, E.J., McIntosh, A., Meyer, E.I., Miliša, M., Mlambo, M.C., Moleón, M., Morais, M., Negus, P., Niyogi, D., Papatheodoulou, A., Pardo, I., Pařil, P., Pešić, V., Piscart, C., Polášek, M., Rodríguez-Lozano, P., Rolls, P.J., Sánchez- Montoya, M.M., Savić, A., Shumilova, O., Steward, A., Taleb, A., Uzan, A., Vander Vorste, R., Waltham, N., Woelfle- Erskine, C., Zak, D. Zarfl, C. and Zoppini, A. 2019. Sediment Respiration Pulses in Intermittent Rivers and Ephemeral Streams. Global Biochemical Cycles 33(8): 1251-1263.

- Garcia-Pedrero, A., García-Cervigón, A.I., Olano, J.M, García-Hidalgo, M., Lillo-Saavedra, M., Gonzalo-Martín, C., Caetano, C. and Calderón-Ramírez, S. 2019. Convolutional neural networks for segmenting xylem vessels in stained cross-sectional images. Neural Computing and Applications (in press).

- Parra, V., Arumí, J.L., Muñoz, E. and Paredes, J. 2019. Characterization of the groundwater storage systems in south-central Chile: An approach based on recession flow analysis. Water 11(11): 2324-2337.

- Quezada, G.R., Ramos, J., Jeldres, R.I., Robles, P. and Toledo., P.G. 2019. Analysis of the flocculation process of fine tailings particles in saltwater through a population balance model. Separation and Purification Technology 237: 116319.

- Cárdenas-Soracá, D., Tucca, F., Mardones, C. and Barra, R. 2019. Development of an analytical methodology for the determination of organochlorine pesticides by ethylene-vinyl acetate passive samplers in marine surface waters based on ultrasound-assisted solvent extraction followed with headspace solid-phase microextraction and gas chromatography-tandem mass spectrometry. Journal of Chromatography A 1605: 360341.

- Quezada, G., Saavedra, J., Rozas, R. and Toledo, P. 2019. Molecular dynamics simulations of the conformation and diffusion of partially hydrolyzed polyacrylamide in highly saline solutions. Chemical Engineering Science 214: 115366.

- Vásquez-Lavín, F., Ponce, R., Hernández, J.I., Gelcich, S., Carrasco, M. and Quiroga, M. 2019. Exploring dual discount rates for ecosystem services: Evidence from a marine protected area network. Resource and Energy Economics 55: 63-80.

- Figueroa, F.A., Abdala-Díaz, R., Hernández, V., Pedreros, P., Aranda, M., Cabrera-Pardo, J., Pérez, C., Becerra, J. and Urrutia, R. Invasive diatom Didymosphenia geminata as a source of polysaccharides with antioxidant and immunomodulatory effects on macrophage cell lines. Journal of Applied Phycology 32: 93-102.

- Baeza, A., Bürger, R., Mulet, P and Zorío, D. 2019. WENO reconstructions of unconditionally optimal high order. Siam Journal on Numerical Analysis 57(6): 2760 – 2784.

- Santander, C., Ruiz, A., García, S., Aroca, R., Cumming, J. and Cornejo-Rivas, P. 2019. Efficiency of two arbuscular mycorrhizal fungal inocula to improve saline stress tolerance in lettuce plants by changes of antioxidant defense mechanisms. Journal of the Science of Food and Agriculture 100: 1577-1587.

- Medina, J., Monreal, C., Orellana, L., Calabi-Floody, M.C., González, M.E., Meier, S., Borie, F. and Cornejo-Rivas, P. 2019. Influence of saprophytic fungi and inorganic additives on enzyme activities and chemical properties of the biodegradation process of wheat straw for the production of organo-mineral amendments. Journal of Environmental Management 255: 109922.

- Rosseto Camiloti, P., Valdés, F., Palladino Delforno, T., Bartacek, J., Zaiat, M. and Jeison, D. 2018. A membrane aerated biofilm reactor for sulfide control from anaerobically treated wastewater. Environmental Technology 40: 2354-2363.

- Gutiérrez, L., Uribe, L., Hernández, V., Vidal, C. and Texeira, R. 2020. Assessment of the use of lignosulfonates to separate chalcopyrite and molybdenite by flotation. Powder Technology 359: 216-225.

- Reyes-Contreras, C. Neumann, P., Barriga, F., Venegas, M., Domínguez, C., Bayona, J.M. and Vidal, G. 2018. Organic micropollutants in sewage sludge: influence of thermal and ultrasound hydrolysis processes prior to anaerobic stabilization. Environmental Technology 41: 1358-1365.

- Vázquez-López,M., Amabilis-Sosa, L., Moeller-Chávez, G., Roé-Sosa, A., Neumann, P. and Vidal, G. 2018. Evaluation of the ultrasound effect on treated municipal wastewater. Environmental Technology 40(27): 3568-3577.

- Ossa-Moreno, J., Keir, G., McIntyre, N., Cameletti, M. and Rivera, D. 2018. Comparison of approaches to interpolating climate observations in steep terrains with low-density gauging networks. Hydrology and Earth System Sciences 23: 4763-4781.

No ISI Publications

- Bürger, R., Torres, H. and Vega, C.A. 2019. An entropy stable scheme for the multiclass Lighthill-Whitham-Richards traffoc model. Advances in Applied Mathematics and Mechanics 11(5): 1022-1047.

- Marino, G., Zaccaria, D., Snyder, R.L., Lagos, O., Lampinen, B.D., Ferguson, L., Grattan, S.R., Little, C., Shapiro, K., Maskey, M.L., Corwin, D.L., Scudiero, E. and Sanden, B.L. 2019. Actual Evapotranspiration and Tree Performance of Mature Micro-Irrigated Pistachio Orchards Grown on Saline-Sodic Soils in the San Joaquin Valley of California. Agriculture 9(4): 76.

- Campos, J.L., Crutchik, D., Franchi, O., Pavissich, J.P., Belmonte, M., Pedrouso, A., Mosquera-Corral A. and Val del Río, A. Nitrogen and Phosphorus Recovery from Anaerobically Pretreated Agro-Food Wastes: A Review. Frontiers in Sustainable Food Systems 2: 1-11.

- Basualto, S. Del Valle, J., Gil, M.V., Figueroa, R., Parra, O., González, A. and Stehr, A. Modelos de gestión, conflictos y mediación en cuencas hidrográficas: los casos de España y Brasil y su aplicabilidad a Chile. Revista del Programa Hidrológico Internacional para América Latina y el Caribe (Aqua-LAC) 11: 66 – 76.

- Acuña, A., Echeverría, C., Godoy-Faúndez, A. and Vásquez, F. The role of climate variability in convergence of residential water consumption across Chilean localities. Environmental Economics and Policy Studies 22(1): 89-108.

- Wallace, R., Lamilla, C., Pieretti, J., Díaz, M., Tortella, G., Diez, M.C., Barrientos, L., Seabra, A. and Rubilar, O. Comparison of antibacterial and antibiofilm activities of biologically synthesized silver nanoparticles against several bacterial strains of medical interest. Energy, Ecology and Environment 4(4): 143–159.

- Pannunzio, A., Holzapfel, E., Texeira, P., Brenner, J., Dufour, F. and Demarco, G. Water and Energy Footprint in a Drip Irrigated and Sprinkler Frost Protected Blueberry Crop in Concordia, Argentina. 3rd World Irrigation Forum (WIF3), 1-7 September 2019, Bali, Indonesia ST-3.2 W.3.2.08: 1-6.

- Pedreros Troncoso, P., Torrejón, F., Álvarez, D. and Urrutia, R. Reconstruyendo la degradación ambiental del Lago Vichuquén, Región del Maule, Chile, mediante el uso de registros históricos documentales. HALAC – Historia Ambiental, Latinoamericana y Caribeña 9: 149-177.

- Bahamonde, P., Berrocal, C., Barra, R., Mcmaster, M., Munkittrick, K. and Chiang, G. 2019. Mucus phosphoproteins as an indirect measure of endocrine disruption in native small-bodied freshwater fish, exposed to wastewater treatment plant and pulp and paper mill effluents. Gayana 83(1): 10–20.

- Tainá Mota, V., Zaiat, M. and Jeison, D. 2019. Effects of effluent acidification on filtration characteristics in sidestream AnMBRs. Bioresource Technology Reports 8: 100346.

- Diez, M.C. 2019. Protección del Recurso Hídricos en la Agricultura. Revista Campo Tecnología I+D+i Edición 14: 18 – 21.

- Rolim, W., Lamilla, C., Pieretti, J., Nascimento, M., Ferreira, F., Tortella, G., Diez, M., Barrientos, L., Rubilar, O. and Seabra, A. 2020. Antibacterial activity and cytotoxicity of silver chloride/silver nanocomposite synthesized by a bacterium isolated from Antarctic soil. BioNanoScience 10: 136-148.

- García, K., Arumí, J.L., Uslar, N., Joublanb, J.P. and Toledo, P. 2019. Calidad de agua de cuencas Choapa, Maipo y Rapel a la luz de la normativa de riego NCh1333. Redagrícola Chile 107: 50-52.

Books or Book Chapters

BOOKS

- Muñoz, M.D.; Azocar, G.; Cornejor, S.; Aguayo, M.; Figueroa, R. 2019. Diversidad en la Cuenca del Lago Lanalhue: comprendiendo la relación entre su patrimonio natural y cultural. Secretaría Regional Ministerial del Medio Ambiente, Gobierno de Chile, Centro de Ciencias Ambientales EULA-Chile, Universidad de Concepción/ Chile. 107 páginas.

- Rojas Hernández, J. 2018. América Latina: Expansión Capitalista, conflictos sociales y ecológicos. RIL Editors/ Santiago/Chile. 362 páginas.

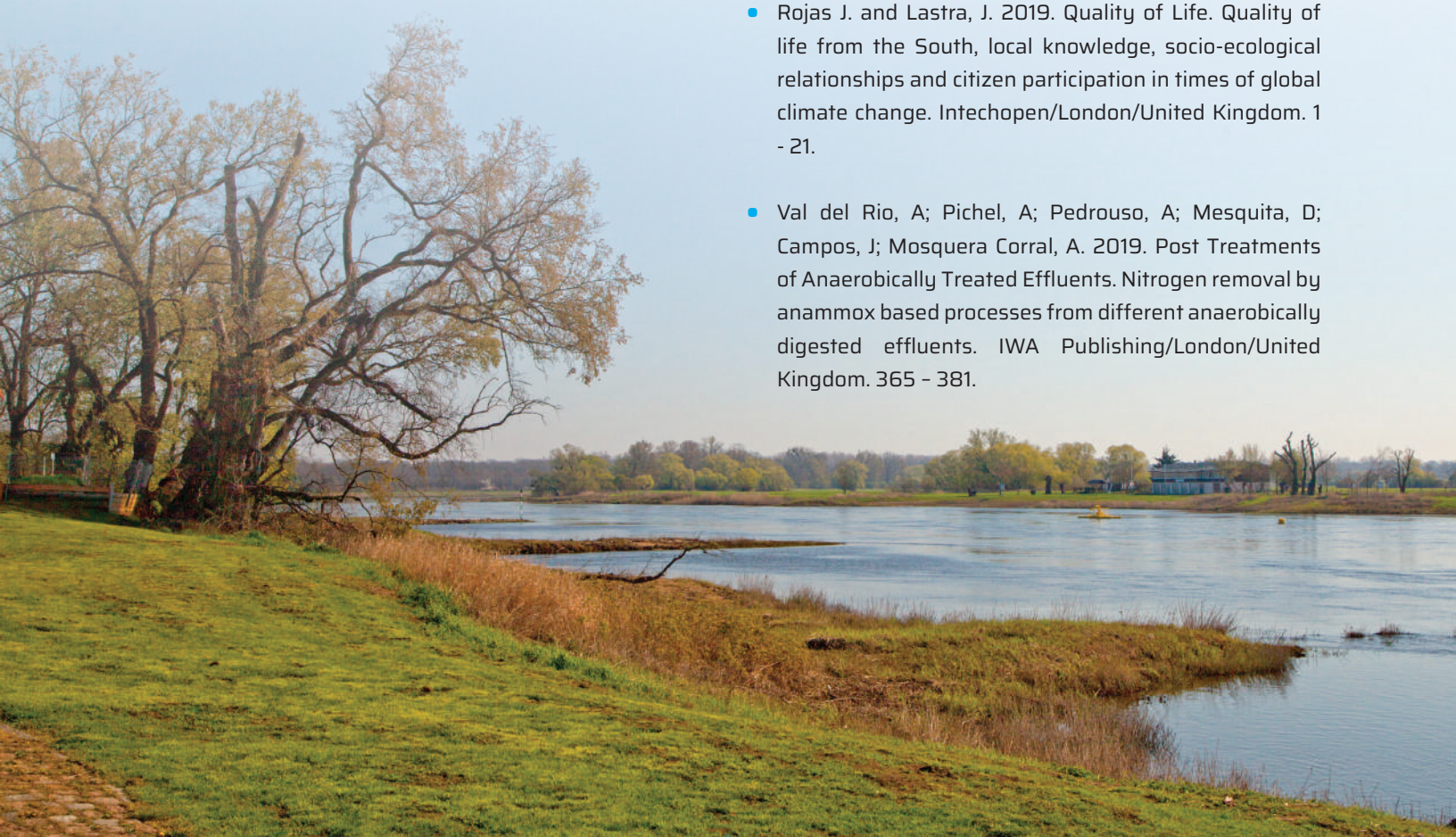
BOOK CHAPTERS

- Arumí, J.L., Muñoz, E. and Oyarzún, R. 2019. Groundwaters. Andean Mountain Groundwater, Drinking Water Sources, and Vulnerability: A Case Study in Central Chile. Intechopen/London/United Kingdom. 1 - 14.

- Rivera, D.; Alvez, A.; De la Hoz, F. 2019. La regulación de las aguas: nuevos desafíos del siglo XXI. Actas de las II Jornadas del régimen jurídico de las aguas. Transparentando las aguas: Rol de los Registros Públicos sobre Recursos Hídricos en Chile. Desafíos para el estándar de seguridad hídrica. Editorial DER Ediciones en La Regulación de las Aguas: Nuevos Desafíos del Siglo XXI/Santiago/Chile. 431 - 460.

- Rojas J. and Lastra, J. 2019. Quality of Life. Quality of life from the South, local knowledge, socio-ecological relationships and citizen participation in times of global climate change. Intechopen/London/United Kingdom. 1 - 21.

- Val del Rio, A; Pichel, A; Pedrouso, A; Mesquita, D; Campos, J; Mosquera Corral, A. 2019. Post Treatments of Anaerobically Treated Effluents. Nitrogen removal by anammox based processes from different anaerobically digested effluents. IWA Publishing/London/United Kingdom. 365 – 381.



MINING

6. DISSEMINATION AND EXPLOITATION OF RESULTS

CRHIAM
CENTRO DE RECURSOS HÍDRICOS PARA LA AGRICULTURA Y LA MINERÍA
ANID/FONDAP/15130015

CRHIAM's communication strategy in 2019 was to make visible the work of the members of the Center, their research and the contribution of research to public policies and society.

CRHIAM Lecture Cycle

Among the activities carried out within the annual agenda framework , a cycle of monthly talks was held, which took place on the first Thursday of each month. The 2019 CRHIAM lecture cycle aims to provide opportunities to internalize the topics CRHIAM researchers are working on and exchange knowledge among academics, students, and support personnel to promote interdisciplinary collaboration and Center members´ interaction in a scientific context that contributes to the performance of everyone. The format of these lectures 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 exchanging ideas between the presenter and the audience. Finally, a graphic design was developed to promote the lecture cycle and show continuity in conferences held during the year.

The first lecture was given by Dr. Fernando Concha, CRHIAM principal investigator, and was titled "Water for mining". During his presentation, Dr. Concha addressed different topics related to water resources in mining processes and highlighted that while the mining industry currently recovers a large part of the water it uses, the current scarcity scenario requires greater efficiency and that mining companies search for new technologies. He also spoke of the social conflicts in areas with extreme water scarcity, where communities coexist with mining activity. Thus, finding alternatives both to ensure human consumption needs are met and satisfy the industry´s demands is a challenge for research projects such as CRHIAM. Figure 14 shows the attendees of the first lecture cycle.

FIGURE 14.
2019 CRHIAM Lecture Cycles.

Table 7 presents each of the topics addressed in the 2019 CRHIAM Lecture cycle.

TABLE 7.
2019 CRHIAM lecture cycle.

PRESENTATOR	TITLE OF PRESENTATION
Dr. Fernando Concha	Water for mining
Dr. José Luis Arumi / Dr. Verónica Delgado	Artificial recharge of groundwater in Chile: State of the art and technical and legal aspects
Dr. Roberto Urrutia	Sediment records and climate change
Dr. Octavio Lagos	Evapotranspiration using remote sensors: Vegetation indices and energy balances
Dr. Ricardo Barra	Water pollution
Dr. Jorge Rojas	The social perception of water resources and climate change
Dr. María Cristina Diez	Biopurification system for pesticide-polluted water
Dr. Pedro Toledo	Lithium: availability, concentration, actors and look to the future
Dr. Gladys Vidal	Water in rural communities

Contributions to policy makers and other targeted groups

PRESS APPEARANCES:

During 2019, CRHIAM researchers have been permanently participating in different discussion instances on public policies related to water resources. It is in this sense that contribution to policy makers and stakeholders has been focused in outreach of the society, educating on the many aspects of water resources and the analysis of different law modification projects that are been discussed at the minister level and or at the Congress (both senate and representative levels). Notably, this year CRHIAM some of our researchers had been asked to contribute to write analysis of law project that are in discussion in different media like Mercurio Legal (which is the referent of such debate in Chile) or other nationwide newspapers: El Mercurio (Santiago Body: Legal, Field), La Discusión (Chillán), Diario El Sur (Concepción), Diario de Concepción (Concepción), El Mostrador (Santiago), La Tercera (Santiago), La Segunda (Santiago), Panorama UdeC (Concepción), among others. Figure 15 shows some of these press appearances.

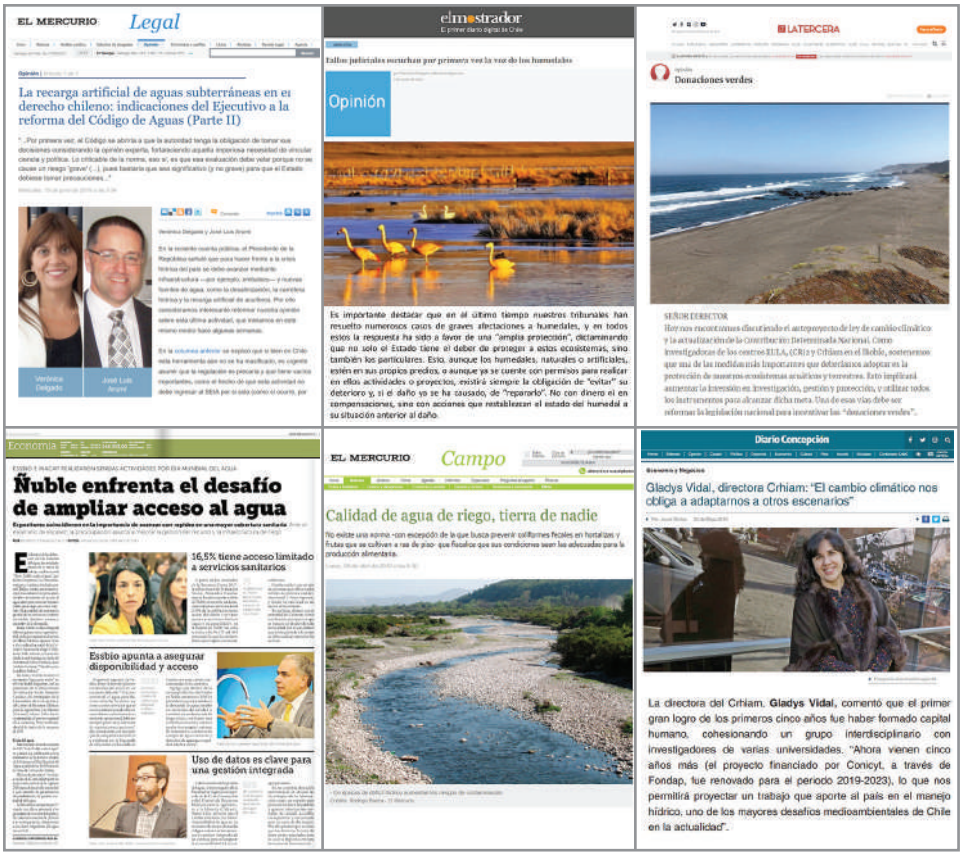


FIGURE 15.
2019 CRHIAM press appearances.

In 2018 and 2019, 6 capsules on the water safety research carried out by CRHIAM were set up in programs on national TV 24 hours in the Program "Explorers: From the Atom to the Cosmos" with a presentation the CRHIAM live in the set of the national channel. Also, other interviews on other television channels such as CNN Chile and regional were made during 2019. Figure 16 shows the appearance in the press of Dra. Gladys Vidal in this program web site.

FIGURE 16.
Press appearances: Climate change and water security, Dr. Gladys Vidal in Channel 24 Hours web site publications.

ORGANIZATION OF AND ATTENDANCE AT MEETINGS WITH PUBLIC INSTITUTIONS:

This permanent work contribution to policymakers had positioned CRHIAM as a referent. For example, the Environmental Minister asked for CRHIAM´s support for the discussion of a new standard for treated wastewater infiltration (DS 46/ 2002 "Establish a standard of waste issuance liquids to groundwater"), and the National Irrigation Commission (CNR) for Artificial Groundwater Recharge at the Ñuble and Bio-Bio Regions. (see Figure 17).

FIGURE 17.
Meeting of CRHIAM members and Ministry of the Environment representatives to review advances in the revision of DS46.

Also, Water Authorities (DGA) sought CRHIAM´collaboration to develop proposals for water resources management in different regions. Additionally, some of our researchers have been asked to contribute to discussing legal projects; for example, Verónica Delgado was invited to the Chamber of Deputies to discuss a proposal related to water user organizations (see Figure 18).

FIGURE 18.
Dr. Verónica Delgado Presentation before the Water Resources and Desertification Commission of the Chamber of Deputies.

Another important issue was the collaboration of CRHIAM for the organization of the COP 25 in Chile. The Director of CRHIAM was asked to participate in a team representing the Biobio Region at the COP 25. Moreover, several of our researchers, led by Dra Verónica Delgado, prepared scientific documentation related to water resources and Climate Change. The Figure 19 show "Path to COP25: contributions from UdeC" discussion attendees.

FIGURE 19.
"Path to COP25: contributions from UdeC" discussion attendees.

OUTREACH TO SOCIETY

Outreach is a permanent task of CRHIAM, as we invest many hours attending meetings, conferences, and talks to the general public. Good examples of our permanent work are conferences organized with the support of CRHIAM, activities developed by the center like the Water Forum or the summer schools, our collaboration with Explora Conicyt and other programs, talks to schools, and the general public. Specifically, during the year 2019, we organized the Waterlat Globacit Conference in Concepción and contributed to the Water Congress and the AIDIS Conference organization in Santiago.

On the other hand, Dr. Felipe de la Hoz is in charge of performing outreach connected to the research of CRHIAM with agricultural technical high schools and farmers. The objective is to transfer knowledge on irrigation in agriculture. The activities of 2019 are grouped into two lines of action.

Line 1. Technological dissemination and transfer of knowledge to farmers. In this line, there are 3 different kinds of activities:

a) Field days on the use of irrigation technologies.
b) Talks on efficient management and use of water resources.
c) Irrigation management and control technologies.

Line 2. Formation of human capital. The kind of activities of this line are:

a) Diplomas in irrigation for professionals.
b) Short courses for companies and public services (INDAP).
c) Classes of equipment and instruments for students of the agricultural school El Carmen de San Fernando.
d) Implement Irrigation Technology Laboratories in Agricultural Technical Licenses, through agreements with public and private actors.

FIGURE 20.
Photographic record of some outreach to society.

ACTIVITIES ORGANIZED BY CRHIAM

The activities organized by CRHIAM either collaboratively or exclusively are divided into seminars, summer schools, congresses, and water forums.

The water forums were held between March 20 and 26, 2019, to celebrate World Water Day. Five events were held in different parts of the country, the main one being the World Water Day event: "Water security: Leave no one behind", held at the University of Concepción. On World Water Day, CRHIAM and EULA-Chile, organized the Water Forum, aligning with the UN´s theme for the year. Dr. Gladys Vidal, CRHIAM director, expressed her thanks for the attendance of university authorities and representatives of government bodies and private organizations and delved into the concept of water security, CRHIAM's main line of work in the 2019-2023 period.

FIGURE 21.
Photographs of the five water forums organized by CRHIAM in 2019.

Other activities organized by CRHIAM include seminars, conferences, and summer schools. For example, in January 2019, a summer school was held that had a conversation and four courses. Figure 22 shows the poster for the 2019 summer school (left) and photographs of the discussion and courses taken during this school (right).

FIGURE 22.
CRHIAM 2019 Summer school.

Figure 23 shows posters and photographs of other events organized by CRHIAM, such as Water Congress 2019, Discussion: "The urgent signing of the Escazú Agreement in Chile: for environmental information, participation and justice" and X Waterlar-Globacit Annual Meeting, Chile 2019.

FIGURE 23.
Activities organized by CRHIAM 2019.

AGRICULTURE

7. ANNEXES

CRHIAM
CENTRO DE RECURSOS HÍDRICOS PARA LA AGRICULTURA Y LA MINERÍA
ANID/FONDAP/15130015

References per research line

RL1. Efficient use of water in agriculture and mining

- Alvez, A., Aitken, D., Rivera, D., Vergara, M., McIntire, N. and Concha, F. 2019. At a crossroads: Can desalination be suitable public policy solution to address water scarcity in Chile's mining zones. *Journal of Enviromental Management*

- Bürger, R. and Kröker. 2019. Computational uncertainty quantification for some strongly degenerate parabolic convection-diffusion equations, *Journal of Computational and Applied Mathematics*, 348, 490-508.

- Bürger, R., Diehl, S. and Martí, M.D.C. 2019a. A system of conservation laws with discontinuous flux modelling flotation with sedimentation. *IMA Journal of Applied Mathematics*, 84(5), 930-973.

- Bürger, R., Méndez, P.E. and Parés, C. 2019b. On entropy stable schemes for degenerate parabolic multispecies kinematic flow models. *Numerical Methods for Partial Differential Equations*, 35(5), 1847-1872.

- Campos, L. 2019. Experimental methodology for the particle characterization by Analysis of Imagenes. Metallurgical Engineering degree thesis, Universidad de Concepción, Chile. (In progress).

- Céspedes, J.A., T. Baumgartl, T. and Concha, F. 2019. Modelling and monitoring tailings dam operations: Estimation of daily evaporation from a tailing dam using a large aperture scintillometer. *Minerals Engineering On review.*

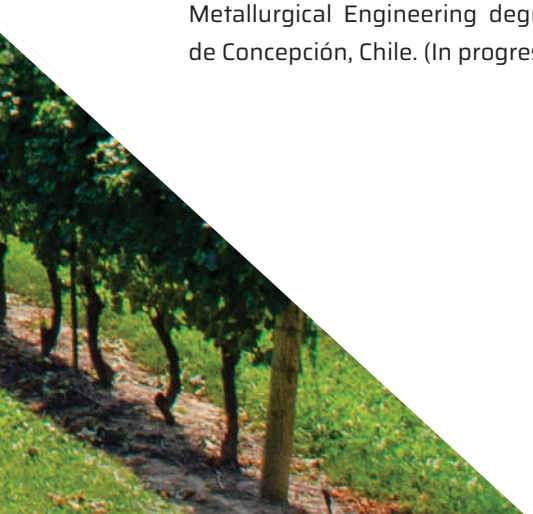
- Concha, F., Betancourt, F. and Cornejo, P. 2019. Patente: Equipo de Clasificación-floculación, en redacción. Del Río, M., Cornejo, P., Betancourt, F., Concha, F. and Ruylov, N., Study of shear rate production in different geometric configuration of hydraulic reactors for ultraflocculation. *Chemical Engineering Research and Design*, 141, 133-14.

- Concha, F and Vergara M. 2019. Design of instrumentation to determine simultaneously five parameters of the feed material of thickeners. Corfo Project 19IRB-111921.

- Del Río, M., Cornejo, P., Betancourt, F., Concha, F. and Ruylov, N. 2019. Study of shear rate production in different geometric configuration of hydraulic reactors for ultraflocculation. *Chemical Engineering Research and Design,* 141, 133-143.

- Fernández, F.J., Blanco, M., Ponce, R. D., Vásquez-Lavín, F. and Roco, L. 2019. Implications of climate change for semi-arid dualistic agriculture: a case study in Central Chile. *Regional environmental change,* 19(1), 89-100.

- García, A. and Betancourt, F. 2019. Conservative mathematical model and numerical simulation of batch gravity settling with coalescence of liquid-liquid dispersions. *Chemical Engineering Science*, 207, 1214-1229.



- García-Pedrero, A., Lillo-Saavedra, M., Rodríguez-Esparragón, D. and Gonzalo-Martín, C. 2019a. Deep learning for automatic outlining agricultural parcels: exploiting the land parcel identification system. *IEEE Access,* 7, 158223-158236.

- Garcia-Pedrero, A., Garcia-Cervigon, A. I., Olano, J. M., Garcia-Hidalgo, M., Lillo-Saavedra, M., Gonzalo-Martin, C. and Calderon-Ramirez, S. 2019b. Convolutional neural networks for segmenting xylem vessels in stained cross-sectional images. *Neural Computing and Applications*, 1-13.

- Gavilán, V., Lillo-Saavedra, M., Holzapfel, E., Rivera, D. and García-Pedrero, A. 2019. Seasonal crop water balance using harmonized landsat-8 and sentinel-2 time series data. *Water*, 11(11), 2236.

- Gutiérrez, L. Minerales de Arcilla: Efectos en la Flotación de Minerales, 291, 1-11 (2019).

- Gutierrez, L., Uribe, L., Hernandez, V., Vidal, C. and Mendonça, R.T. 2019. Assessment of the use of lignosulfonates to separate chalcopyrite and molybdenite by flotation. *Powder Technology*, 359, 216-225.

- Herrera, M., Candia, C., Rivera, D., Aitken, D., Brieba, D., Boettiger, C., Donoso, G. and Godoy-Faúndez, A. 2019. Understanding water disputes in Chile with text and data mining tools. *Water International*, 44(3), 302-320.

- Jeldres, R., Uribe, L., Cisternas, L., Gutiérrez, L., Leiva, W. and Valenzuela, J. 2019. The effect of clay minerals on the process of flotation of copper ores-A critical review. *Applied Clay Science*, 170, 57-69.

- Marino, G., Zaccaria, D., Snyder, R. L., Lagos, O., Lampinen, B. D., Ferguson, L. et al. 2019. Actual evapotranspiration and tree performance of mature micro-irrigated pistachio orchards grown on saline-sodic soils in the San Joaquin Valley of California. *Agriculture*, 9(4), 76.

- Ossa-Moreno, J., Keir, G., McIntyre, N., Cameletti, M. and Rivera, D. 2019. Comparison of approaches to interpolating climate observations in steep terrain with low-density gauging networks. *Hydrology and Earth System Sciences*, 23(11), 4763-4781.

- Paredes, A., Acuña, S. M., Gutiérrez, L. and Toledo, P. G. Zeta potential of pyrite particles in concentrated solutions of monovalent seawater electrolytes and amyl xanthate. *Minerals,* 9(10), 584.

- Pereira, A. 2019. Dynamic simulator and dynamic thickening column to test the new control strategy. Ph. D. Thesis, Universidad de Concepción, Chile. (In progress).

- Ramirez, A., Gutierrez, L. and Laskowski, J. 2019. Use of “oily bubbles” and dispersants in flotation of molybenite in fresh and seawater. *Mineral Engineering* (submitted).

- Rivera, D., Gutierrez, K., Valdivia-Cea, W., Zambrano-Bigiarini, M., Godoy-Faúndez, A., Álvez, A. and Farías, L. 2019. Validation of cryogenic vacuum extraction of pore water from volcanic soils for isotopic analysis. *Water,* 11(11), 2214.

- Rulyov, N.N., Kravtchenko, O. and Concha, F. 2019. Effects of suspension dispersity and concentration on flocculation efficiency in static and dynamic flocculators. *Journal of Metallic Material Research*, 1(01), 9-15.

- Seal, A., Garcia-Pedrero, A., Bhattacharjee, D., Nasipuri, M., Lillo-Saavedra, M., Menasalvas, E. and Gonzalo-Martin, C. 2019. Multi-scale RoIs selection for classifying multi-spectral images. *Multidimensional Systems and Signal Processing*, 1-25.

- Souto, C., Lagos, O., Holzapfel, E., Maskey, M. L., Wunderlich, L., Shapiro, K., Marino, G., Snyder, R. and Zaccaria, D. 2019. A modified surface energy balance to estimate crop transpiration and soil evaporation in micro-irrigated orchards. *Water,* 11(9), 1747.

- Vidal, C. 2019. Equipo de Clasificación-floculación. Metallurgical Engineering degree thesis, Universidad de Concepción, Chile. (In progress).

RL2: New water sources for agriculture, mining and communities

- Achim, C.V., Rozas, R.E, Toledo, P.G. 2019a. Flow around a cylinder. Comparison between standard and first order consistent Smooth Particle Hydrodynamics. Internal Report.

- Achim, C.V., Rozas, R.E, Concha, F., Toledo, P.G. 2019b. Comparison between standard, zeroth and first order consistent Smoothed Particle Hydrodynamics for flow around a cylinder. *International Journal of Computational Fluid Mechanics* (submitted).

- Achim, C.V., Rozas, R.E, Toledo, P.G. 2019c Semi-Decoupled First-Order Correction for Smoothed Particle Hydrodynamics. *Applied Mathematical Modeling* (submitted).

- Achim, C.V., Rozas, R.E, Toledo, P.G. 2019d. Semi-Decoupled Second-Order Consistency Correction for the Smoothed Particle Hydrodynamics. *Applied Mathematical Modeling* (submitted).

- Cruz, C., Reyes, A., Jeldres, R.I., Cisternas, L.A. and Kraslawski, A. 2019. Using partial desalination treatment to improve the recovery of copper and molybdenum minerals in Chilean mining industry. *Industrial & Engineering Chemistry Research*, 58, 8915-8922.

- García, K., Arumí, J.L., Uslar, N., Joublan, J.P., Toledo, P.G. 2019a. Investigating to reduce salinity and metal content in irrigation waters. *Agrid* October 2019.

- García, K., Arumí, J.L., Uslar, N., Joublan, J.P., Toledo, P.G. 2019b. Water quality of Choapa, Maipo and Rapel basins in light of irrigation regulations NCh1333. *Red Agricola* 107 50-52.

- Jeldres, R. I., Uribe, L., Cisternas, L. A., Gutierrez, L., Leiva, W. H. and Valenzuela, J. 2019a. The effect of clay minerals on the process of flotation of copper ores-A critical review. *Applied Clay Science,* 170, 57-69.
- Jeldres, R.I., Piceros, E.C., Leiva, W.H., Toledo, P.G., Quezada, G.R., Robles, P.A. and Valenzuela, J. 2019b. Analysis of silica pulp viscoelasticity in saline media: the effect of cation size. *Minerals,* 9(4), 216.
- Jeldres, M., Piceros, E., Robles, P. A., Toro, N. and Jeldres, R. I. 2019c. Viscoelasticity of quartz and kaolin slurries in seawater: importance of magnesium precipitates. *Metals,* 9(10), 1120-1132, 2019.
- Paredes, A., Acuña, S. M., Gutiérrez, L. and Toledo, P.G. 2019a. Zeta potential of pyrite particles in concentrated solutions of monovalent seawater electrolytes and amyl xanthate. *Minerals,* 9(10), 584.
- Paredes, Á., Acuña, S. M. and Toledo, P.G. 2019b. AFM Study of pyrite oxidation and xanthate adsorption in the presence of seawater salts. *Metals,* 9(11), 1177-1193.
- Quezada, G. R., Rozas, R. E. and Toledo, P.G. 2019a. Ab initio calculations of partial charges at kaolinite edge sites and molecular dynamics simulations of cation adsorption in saline solutions at and above the pH of zero charge. *The Journal of Physical Chemistry C,* 123(37), 22971-22980.
- Quezada, G., Toledo, P.G. 2019a. Structure of the Interface between Lithium-Rich Spodumene and Saltwater by Density Functional Theory Calculations and Molecular Dynamics Simulation. *The Journal of Physical Chemistry C.*
- Quezada, G.R., Saavedra, J., Rozas, R. and Toledo, P.G. 2019b. Molecular dynamics simulations of the conformation and diffusion of partially hydrolyzed polyacrylamide in highly saline solutions. *Chemical Engineering Science,* 115366.
- Quezada, G.R., Ramos, J., Jeldres, R.I., Robles, P., and Toledo, P.G. 2019d. Analysis of the flocculation process of fine tailings particles in saltwater through a population balance model. Separation and Purification Technology, 116319
- Robles, P., Piceros, E., Leiva, W.H., Valenzuela, J., Toro, N. and Jeldres, R.I. 2019. Analysis of sodium polyacrylate as a rheological modifier for kaolin suspensions in seawater. *Applied Clay Science*, 183, 105328-105333.
- Saldaña, M., González, J., Jeldres, R.I., Villegas, Á., Castillo, J., Quezada, G. and Toro, N. 2019. A Stochastic model approach for copper heap leaching through Bayesian networks. *Metals*, 9(11), 1198-1212.
- Wagemann, E., Walther, J.H., Cruz-Chú, E.R. and Zambrano, H.A. 2019. Water flow in silica nanopores coated by carbon nanotubes from a wetting translucency perspective. *The Journal of Physical Chemistry C*, 123(42), 25635-25642.

RL3: Availability and water quality for agriculture and mining under climate change

- Almanza, V., Pedreros, P., Laughinghouse IV, H. D., Félez, J., Parra, O., Azócar, M. and Urrutia, R. 2019. Association between trophic state, watershed use, and blooms of cyanobacteria in south-central Chile. *Limnologica*, 75, 30-41.

- Arriagada, L., Rojas, O., Arumí, J. L., Munizaga, J., Rojas, C., Farias L. and Vega, C. 2019. A new method to evaluate the vulnerability of watersheds facing several stressors: A case study in Mediterranean Chile. *Science of the Total Environment,* 651, 1517–1533.

- Cárdenas-Soracá, D.M., Tucca, F.I., Mardones-Peña, C.A. and Barra-Ríos, R.O. 2019. Development of an analytical methodology for the determination of organochlorine pesticides by ethylene-vinyl acetate passive samplers in marine surface waters based on ultrasound-assisted solvent extraction followed with headspace solid-phase microextraction and gas chromatography-tandem mass spectrometry. *Journal of Chromatography A,* 1605.

- Climent, M. J., Coscollà, C., López, A., Barra, R. and Urrutia, R. 2019a. Legacy and current-use pesticides (CUPs) in the atmosphere of a rural area in central Chile, using passive air samplers. *Science of The Total Environment,* 662, 646-654.

- Climent, M. J., Herrero-Hernández, E., Sánchez-Martín, M. J., Rodríguez-Cruz, M. S., Pedreros, P. and Urrutia, R. 2019b. Residues of pesticides and some metabolites in dissolved and particulate phase in surface stream water of Cachapoal River basin, central Chile. *Environmental Pollution,* 251, 90-101.

- Duhalde, D.J., Arumí, J. L., Oyarzún, R.A. and Rivera, D.A. 2018. Fuzzy-based assessment of groundwater intrinsic vulnerability of a volcanic aquifer in the Chilean Andean Valley. *Environmental monitoring and assessment,* 190(7), 390.

- Escanilla, C., A.cayaga, H., Kinnard, C. and Urrutia, R. 2019. Evaluation of the impact of climate change on runoff generation in an Andean glacier basin. Presented at the II Meeting of the Chilean Society of the Cryosphere, La Serena. Chile. May 9 – 10, 2019.

- Markovich, K., Dahlke, H., Arumi, J.L., Maxwell, R. and Fogg, G. E. 2019. Bayesian hydrograph separation in a minimally gauged alpine watershed in central Chile. *Journal of Hydrology,* 575, 1288-1300.

- Muñoz, E., Guzmán, C., Medina, Y., Boll, J., Parra, V. and Arumí, J. L. 2019. An adaptive basin management rule to improve water allocation resilience under climate variability and change-A case study in the Laja Lake basin in southern Chile. *Water,* 11(8), 1733-1741.

- Orrego, R. Mark Hewitt, L., McMaster, M., Chiang, G., Quiroz, M., Munkittricke, K., Gavilán, J.F. and Barra, R. 2019. Assessing wild fish exposure to ligands for sex steroid receptors from pulp and paper mill effluents in the Biobio River Basin, Central Chile. *Ecotoxicology and environmental safety*, 171, 256-263.

- Oyarzún J., Nuñez, J., Fairley, J.P., Tapia, S., Alvarez, D., Maturana, H., Arumi, J.L., Aguirre, E., Carvajal, A. and Oyarzun, R. 2019. Groundwater recharge assessment in an arid, coastal, middle mountain copper mining district, Coquimbo Region, north-central Chile. *Mine Water and the Environment,* 38(2), 226-242.

- Parra, V., Arumí, J. L., Muñoz, E. and Paredes, J. 2019a. Characterization of the groundwater storage systems of south-central Chile: An approach based on recession flow analysis. *Water,* 11(11), 2324-2337.

- Parra, V., Arumí, J. L. and Muñoz, E. 2019b. Identifying a suitable model for low-flow simulation in watersheds of south-central Chile: A study based on a sensitivity analysis. *Water*, 11(7), 1506.

- Pedreros, P., Torrejón, F., Alvarez, D. and Urrutia, R. 2019. Reconstruyendo la degradación ambiental del Lago Vichuquén, Región del Maule, mediante el uso de registros históricos-documentales. *HALAC,* 9 (1), 149-177.

- Troncoso, P.C.P., Torrejón, F., Álvarez, D. and Urrutia, R. 2019. Reconstruyendo la degradación ambiental del Lago Vichuquén, Región del Maule, Chile, mediante el uso de registros históricos-documentales. *Historia Ambiental Latinoamericana y Caribeña (HALAC) revista de la Solcha,* 9(1), 149-177.

- Podgórski, J., Kinnard, C., Pętlicki, M. and Urrutia, R. 2019. Performance assessment of TanDEM-X DEM for mountain glacier elevation change detection. *Remote Sensing,* 11(2), 187.

- Sandoval, E., Baldo, G., Núñez, J., Oyarzún, J., Fairley, J., Ajami, H., Arumí, J.L., Aguirre, E., Maturana, H. and Oyarzún, R. 2018. Groundwater recharge assessment in a rural, arid, mid-mountain basin in North-Central Chile. *Hydrological Sciences Journal*, 63(13-14), 1873-1889.

- Uniyal, B., Dietrich, J., Vu, N. Q., Jha, M. K., and Arumí, J.L. 2019. Simulation of regional irrigation requirement with SWAT in different agro-climatic zones driven by observed climate and two reanalysis datasets. *Science of the Total Environment*, 649, 846-865.

RL4: Technology for water treatment and environmental remediation

- Campos, J. L., Crutchik, D., Franchi, Ó., Pavissich, J. P., Belmonte, M., Pedrouso, A., Mosquera-Corral, A. and Val del Río, Á. 2019a. Nitrogen and phosphorus recovery from anaerobically preteated agro-food wastes: A review. *Frontiers in Sustainable Food Systems*, 2, 91.

- Campos, J.L., Dumais, J., Pavissich, J.P., Franchi, O., Crutchik, D., Belmonte, M., Faúndez, M., Jorquera, L., Pedrouso, A., Mosquera-Corral, A. and Val del Río, A. 2019b. Predicting accumulation of intermediate compounds in nitrification and autotrophic denitrification processes: A chemical approach. *BioMed research international*, 2019, 1-9.

- Briceño, G., Lamilla, C., Leiva, B., Levio, M., Donoso-Piñol, P., Schalchli, H., Gallardo, F. and Diez, M.C. 2019. Pesticides-tolerant bacteria from biopurification system to remove commonly used to pesticides to protect water resources. *Environmental Science and Pollution Research* (submitted).

- Chávez, D., Machuca, A., Fuentes-Ramirez, A., Fernandez, N. and Cornejo, P. 2019. Shifts in soil traits and arbuscular mycorrhizal symbiosis represent the conservation status of Araucaria araucana forests and the effects after fire events. *Forest Ecology and Management* (accepted).

- Diez, M.C., Leiva, B., Levio, M. and Gallardo, F. 2019. Innovative technology for pesticides-contaminated water treatment using encapsulated fungi. Presented at the 716th International Conference on Civil and Environmental Engineering (I2C2E), Madrid, España. Nov. 22-23, 2019.

- Fincheira, P., Tortella, G., Duran, N., Seabra, A.B. and Rubilar, O. 2019. Current applications of nanotechnology to develop plant growth inducer agents as an innovation strategy. *Critical reviews in biotechnology*, 40(1), 15-30.

- González, T., Ureta-Zañartu, M.S., Marco, J.F. and Vidal, G. 2019. Effect of Zeolite-Fe on graphite anode in electroactive biofilm development for application in microbial fuel cells. *Applied Surface Science*, 467, 851-859.

- Herrera, W., Leiva, B., Diaz, M., Lamilla, C., Tortela, G., Diez, M.C. and Rubilar O. 2019. Can be synergy between silver nanoparticle and pesticide-degrading microorganisms on chlorpyrifos degradation? Study case. Presented at the 7th International Workshop: Advances in Science and Technology of Bioresources, Pucón. Chile. Nov. 2-4, 2019.

- Leiva, A.M., Albarrán, A., López, D. and Vidal, G. 2019. Evaluation of phytoxicity of effluents from activated sludge and constructed wetland system for wastewater reuse. Water Science and Technology 79(4): 656-667.

- Levío, M., Rubilar, O., Leiva, B., Briceño, G., Tortella, G. and Diez, M.C. 2019. Evaluation of fFixed-bed column packet with easily available lignocellulosic organic wastes residues for atrazine removal of aqueous solutions from farm activities. (Submitted).

- López, D., Sepúlveda, M., Ruiz-Tagle, N., Sossa, K., Uggetti E. and Vidal, G. 2019a. Potential methane production and molecular characterization of bacterial and archaeal communities in a horizontal subsurface flow constructed wetland under cold and warm seasons. *Science of the Total Environment,* 648, 1042–1051.

- López, D., Arismendi, W., Leiva, A. M. and Vidal, G. 2019b. Influence of design and operational parameters on the pathogens reduction in constructed wetland under the climate change scenario. *Review in Environmental Science and Bio/Technology*, 18, 101-125.

- Manosalva, N., Tortella, G., Diez, M.C., Schalchli, H., Seabra, A. B., Durán, N. and Rubilar, O. 2019. Green synthesis of silver nanoparticles: effect of synthesis reaction parameters on antimicrobial activity. *World Journal of Microbiology and Biotechnology*, 35(6), 88.

- Parada, J., Rubilar, O., Diez, M.C., Cea, M., da Silva, A.S.A., Rodríguez-Rodríguez, C.E. and Tortella, G.R. 2019. Combined pollution of copper nanoparticles and atrazine in soil: effects on dissipation of the pesticide and on microbiological community profiles. *Journal of Hazardous Materials,* 361, 228-236.

- Salgado, P., Márquez, K., Rubilar, O., Contreras, D. and Vidal, G. 2019. Phenolic compounds effect on the green synthesis of iron nanoparticles (FexOy-NP) with photocatalytic activity. *Applied Nanoscience* 9(3), 371-385.

- Santander, C., Ruiz, A., García, S., Aroca, R., Cumming, J. and Cornejo, P. 2019a. Efficiency of two arbuscular mycorrhizal fungal inocula to improve saline stress tolerance in lettuce plants by changes of antioxidant defense mechanisms. *Journal of the Science of Food and Agriculture.*

- Santander, C., Sanhueza, M., Olave, J., Borie, F., Valentine, A. and Cornejo, P. 2019b. Arbuscular mycorrhizal colonization promotes the tolerance to salt stress in lettuce plants through an efficient modification of ionic balance. *Journal of Soil Science and Plant Nutrition,* 19(2), 321-331.

- Silambarasan, S., Logeswari, P., Cornejo, P. and Kannan, V. 2019a. Evaluation of the production of exopolysaccharide by plant growth promoting yeast Rhodotorula sp. strain CAH2 under abiotic stress conditions. *International Journal of Biological Macromolecules*, 121, 55-62.

- Silambarasan, S., Logeswari, P., Cornejo, P., Abraham, J. and Valentine, A. 2019b. Simultaneous mitigation of aluminum, salinity and drought stress in Lactuca sativa growth via formulated plant growth promoting *Rhodotorula mucilaginosa* CAM4. *Ecotoxicology and Environmental Safety,* 180, 63-72.

- Silambarasan, S., Logeswari, P., Valentine, A. and Cornejo, P. 2019c. Role of Curtobacterium herbarum strain CAH5 on aluminum bioaccumulation and enhancement of *Lactuca sativa* growth under aluminum and drought stresses. *Ecotoxicology and Environmental Safety*, 183, 109573.

- Silambarasan, S., Logeswari, P., Cornejo, P. and Kannan, V. R. 2019d. Role of plant growth-promoting rhizobacterial consortium in improving the Vigna radiata growth and alleviation of aluminum and drought stresses. *Environmental Science and Pollution Research*, 26(27), 27647-27659.

- Tortella, G. R., Rubilar, O., Cea, M., Rodríguez-Rodríguez, C., Seguel, A. and Parada, J. 2019. Sorption parameters of carbendazim and iprodione in the presence of copper nanoparticles in two different soils. *Journal of Soil Science and Plant Nutrition*, 1-8.

- Val del Rio, A. V., Campos, J. L., Da Silva, C., Pedrouso, A. and Mosquera-Corral, A. 2019. Determination of the intrinsic kinetic parameters of ammonia-oxidizing and nitrite-oxidizing bacteria in granular and flocculent sludge. *Separation and Purification Technology,* 213, 571-577.

- Vázquez-López, M., Amabilis-Sosa, L.E. Moeller-Chávez, G.E., Roé-Sosa, A. Neumann, P. and Vidal G. 2018. Evaluation of the ultrasound effect on treated municipal wastewater. *Environmental Technology,* 40(27), 3568-3577.

RL5: Water governance, ecosystem services and sustainability

- Alvez, A., Ochoa, F., Rivera, D. and De la Hoz, F. 2019. Transparenting the waters: The role of public records on water resources in Chile. Challenges for the water safety standard. In *Water regulation: new challenges of the 21st century. Proceedings of the II Conference of the legal regime of the waters*, Costa, E. and Montenegro S., Eds., Chile, Ediciones DER, pp. 431-460.

- Arumí, J.L., Delgado, V. and Reicher, O. 2019a. Systems of slopes in the Renegado Valley: importance, characteristics and vulnerability. In *Water Security: Water rights, scarcity, impacts and citizen perceptions in times of climate change,* Rojas, J. and Barra R., Eds., Santiago, Chile, Ril editores, pp. 253-271.

- Arumí, J.L., Muñoz, E. and Oyarzún, R. 2019b. Andean mountain groundwater, drinking water sources, and vulnerability: A case study in Central Chile. In Groundwaters-Resource Characterisation and Management Aspects, Modreck, G., Eds., IntechOpen, pp. 1-14.

- Basualto, S., del Valle, J., Gil, M.V., Figueroa, R., Parra, O., González, A. and Stehr, A. 2019. Models of management, conflict and mediation in hydrographic basins: the cases of Spain and Brazil and their applicability to Chile. Aqua-LAC, 11 (1), 66-76.

- Delgado, V. 2019. The reform of the crime of usurpation of water in Chile: only a brushstroke. In Book Tribute teacher Daniel Peñailillo. Thomson Reuters.

- Delgado, V. 2020. Repair environmental damage to groundwater in the courts of Chile. Journal Derecho Privado, 38, 279-310.

- Farías, L., Ubilla K., Aguirre, C., Arredondo-Araya, M., Bedriñana, L., Cienfuegos, R., Delgado, V., Escauriaza, C., Fernández, C., Fernández, M., Gaxiola, A., González, H., Hucke-Gaete, R., Marquet, P., Montecino, V., Morales, C., Narváez, D., Osses, M., Peceño, B., Quiroga, E., Ramajo, L., Sepúlveda, H., Soto, D., Vargas, E., Viddi, F. and Valencia J. 2019. Nine ocean-based solutions to contribute to the NDCs of Chile. Scientific Committee COP25, Table Ocean.
- Novoa, V., Ahumada-Rudolph, R., Rojas, O., Sáez, K., de la Barrera, F. and Arumí, J.L. 2019. Understanding agricultural water footprint variability to improve water management in Chile. *Science of The Total Environment,* 670, 188-199.
- Rojas, J. and Barra, R. 2019. Water Security: Water rights, scarcity, impacts and citizen perceptions in times of climate change. RIL Editores, Santiago de Chile. 344 pp. ISBN 978-956-01-0757-2.

2019 Annual Report CRHIAM

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CENTRO DE RECURSOS HÍDRICOS PARA LA AGRICULTURA Y LA MINERÍA
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