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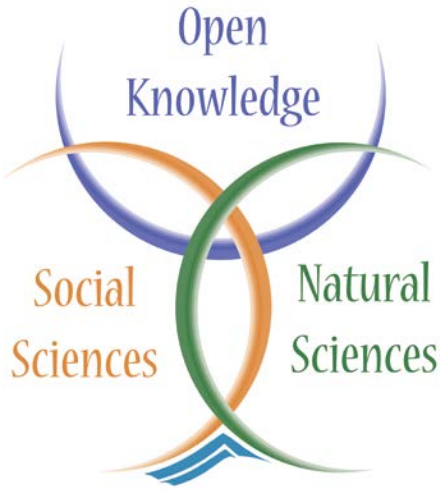

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ARIZONA

UWE BRISTOL University of the West of England

UNIVERSIDAD DE SEVILLA

UNESCO-IHE
Institute for Water Education

Authors: Nuria Hernandez-Mora, Leandro del Moral, Violeta Cabello, Susan Harris, Chloe Fandel, Brian O'Neil, Joan Cortinas, Murielle Coeurdray, Adriana Zuniga Teran, Kremena Boyanova, Stoyan Nedkov, Rositsa Yaneva, Gregg Garfin, Xubin Zeng, Maria A. Sans-Fuentes and Franck Poupeau

Edited by Maria A. Sans-Fuentes

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1. INTRODUCTION AND OBJECTIVES

The 2nd SWAN International Conference "Open Knowledge: Bridging Perspectives to Address Water Challenges" was held at the Doubletree by Hilton Hotel - Reid Park in Tucson (Arizona, USA) during February 16-17, 2016. A Pre-Conference Student Workshop entitled "*Can we Talk? Designing a Transdisciplinary Education Experience*" (Annex 1) was held at the Biosphere 2 facilities on Monday, February 15, 2016. The main conclusions of this Workshop were presented during the Session 3 of the Conference *"How to build a more comprehensive educational experience under a transdisciplinary context*. Moreover, on February 15th, the 7th Progress meeting was held between team leaders and researchers in order to prepare the conference's sessions and to schedule activities for a new grant proposal.

The Conference was organized by SWAN team members and students and professors from the University of Arizona (Annex 2) in the context of the four-year EU-funded SWAN International Cooperation project (Sustainable Water ActioN) which seeks to build and reinforce trans-disciplinary links between researchers in Europe and the USA. Based at the University of Arizona, the team includes prominent scientists from the US and five European countries (Bulgaria, France, Netherlands, Spain and the United Kingdom). A major objective of this project is settle the basis to develop, coordinate and maintain an "Institute for Open Knowledge on Water" (iOKW) as a platform to facilitate transdisciplinary research, education and knowledge exchange at both national and international levels.

The major goals of the Conference were to:

a) Promote open availability and use of knowledge and data in the service of addressing water challenges
b) Find better ways to take advantage of newly emerging tools for sharing and exploiting our growing storehouse of knowledge regarding Water and the Environment
c) Promote stronger links between Natural Scientists, Social Scientists and various Stakeholders Groups (including the General Public)
d) Develop multi-authored white papers on workshop themes

To achieve these goals, the Conference was organized using a workshop format, and was designed to highlight the strengths and challenges involved in adopting a trans-disciplinary perspective to water related issues. An important aspect of the meeting was a focus on the

development and implementation of a trans-disciplinary perspective within the Educational Curriculum. The Conference was organized around 5 main topics:

- Open Knowledge and Transdisciplinarity in the Era of Big Data: What Lessons for Water Governance?
- Water Management in Tucson. Collaborative Research to Understand the Challenges of the Future
- Water, Energy and Food
- Ecosystem Services as a Bridge between Disciplines
- Adaptation to Climate and Other Changes

The general format of the sessions was to begin with two or three brief invited talks (one each on Natural Science, Social Science and Citizen/Stakeholder perspectives) followed by smaller breakout groups charged with discussing and reporting on pre-assigned issues/questions. The sessions were then re-convene to present their reports and engage in a larger group discussion.

As a follow up of the Pre-Conference Student Workshop, during the conference there was a Panel Discussion, where a multi-disciplinary group of students presented a report on their pre-workshop deliberations regarding the topic of “How to Build a More Comprehensive Educational Experience”.

The venue hosted a poster session where, among others, SWAN students were able to disseminate the results from their research on the Tucson Case Study. Also, the organization invited 2 keynotes speakers:

- Dominique Pestre - École des hautes études en sciences sociales, EHESS, Paris (France). Talk title: *The sciences between technology, economy and political regulations.*
- Andrew Comrie - Senior Vice President for Academic Affairs and Provost of The University of Arizona. Talk title: *Transdisciplinarity in education.*

The conferences ended with a moderated discussion (and wrap-up session) focused on the broader topic of Open Knowledge & Bridging Perspectives to Address Water Challenges.

Hundred people from different nationalities (Bulgaria, The Netherlands, Spain, France, United Kingdom, and United States) attended the Conference. Among the attendees there were professors, researchers, students and stakeholders (Annex 3).

To promote the Conference and to help with the registration (free of charge) a website was set up using Drupal 7 (http://www.swanopenknowledge.org/). The website offered all the information regarding the sessions, the abstracts of the posters, the bibliography of the presenters, and the link to book the accommodation in the Doubletree hotel (Figure 1).

The Slides of the presentations, the program of the conference and the contact list of the attendees can be found at http://swanproject.arizona.edu/2nd-swan-international-conference

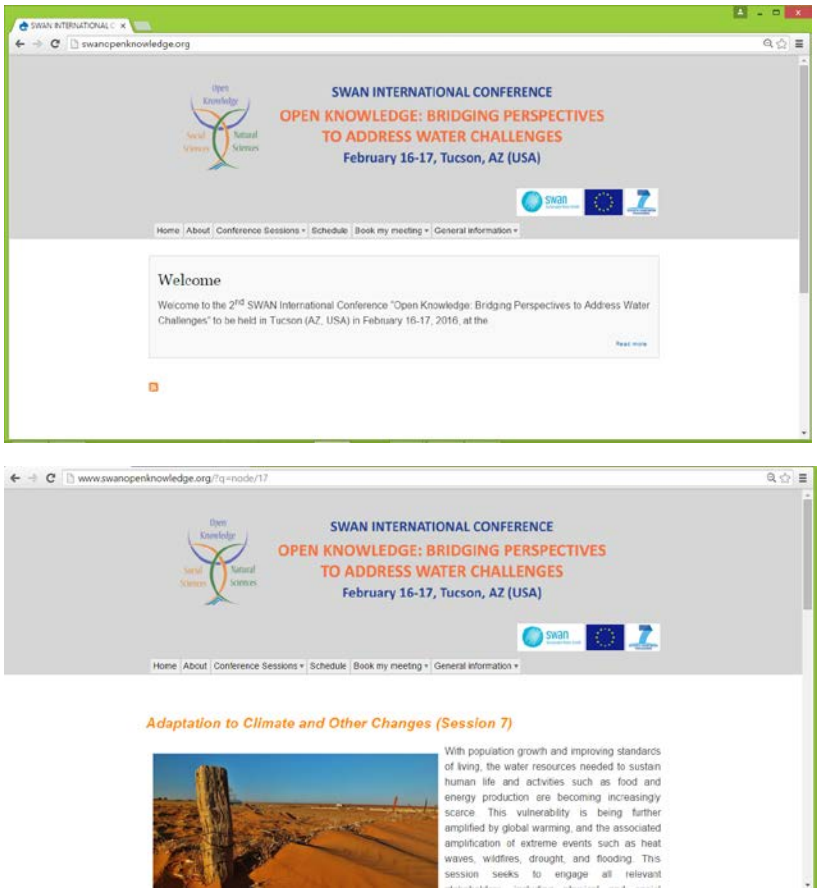

Figure 1. Screenshots of the website

2. CONFERENCE PROGRAM

MONDAY - FEBRUARY 15

6:00 – 8:00	**Registration**

TUESDAY - FEBRUARY 16

8:00 – 9:00	**Registration & Coffee**
9:00 – 9:30	**Introduction**
9:30 – 10:30	**Keynote #1 by Dominique Pestre:** The sciences between technology, economy and political regulations
10:30 – 11:30	**Session 1A:** Posters / Coffee
11:30 – 12:00	**Session 1B:** Presentation of SWAN–book data viewer
12:00 – 1:00	**LUNCH**
1:00 – 1:30	**BREAK**
1:30 – 4:30	**Session 2:** Open Knowledge and Transdisciplinarity in the Era of Big Data: What Lessons for Water Governance?
4:30 – 5:00	**COFFEE BREAK**
5:00 – 6:30	**Session 3:** How to Build a More Comprehensive Educational Experience
6:30 – 9:00	**SOCIAL MIXER**

WEDNESDAY - FEBRUARY 17

8:00 – 8:30	**Registration & Coffee**
8:30 – 9:30	**Keynote #2 by Andrew Comrie:** Transdisciplinarity in Education
9:30 – 12:30	**Session 4:** Water Management in Tucson. Collaborative Research to Understand the Challenges of the Future - **Coffee at 10:30**
	Session 5: Water, Energy and Food - **Coffee at 10:30**
12:30 – 1:30	**LUNCH**
1:30 – 4:30	**Session 6:** Ecosystem Services as a Bridge between Disciplines - **Coffee at 3:30**
	Session 7: Adaptation to Climate and Other Changes - **Coffee at 3:30**
4:30 – 6:00	**Panel Discussion:** Bridging Perspectives - **Snacks at 4:30**

Open Knowledge: Bridging Perspectives to Address Water Challenges

February 16 & 17 – Doubletree-Reid Park Hotel, Tucson, Arizona, USA

Monday *February 15*	Tuesday *February 16*	Wednesday *February 17*	
	Registration & Coffee (8:00 AM – 9:00 MA)	Arrival/Coffee (8:00-8:30am)	
Student Workshop **Can we talk? Designing a transdisciplinary educational experience** **Biosphere 2 Facilities**	**Introduction** *Franck Poupeau and Graciela Schneier* (9:00 AM – 9:30 AM)	**Keynote Talk #2 & Discussion** by *Andrew Comrie*: *"Transdisciplinarity in Education"* (8:30 AM – 9:30 AM)	
	Keynote Talk #1 by *Dominique Pestre*: *"Science, Technology, Economy and Politics"* (9:30 AM – 10:30 AM)	**Session 4:** *"Water Management in Tucson"* (9:30 AM – 12:30 PM)	**Session 5:** *"Water, Energy and Food"* (9:30 AM – 12:30 PM)
	Session 1A: *"Posters"* (10:30 AM – 11:30 AM)		
	Session 1B: *"Presentation of SWAN–book data viewer"* (11:30 AM – 12:00 PM)		
	Lunch (12:00 – 1:00 PM)	Lunch (12:30 PM – 1:30 PM)	
	Break (1:00 PM -1:30 PM)		
	Session 2: *"Open Knowledge and Transdisciplinarity in the Era of Big Data: What Lessons for Water Governance?"* (1:30 PM – 4:30 PM)	**Session 6:** *"Ecosystem Services as a Bridge Between Disciplines"* (1:30 PM – 4:30 PM)	**Session 7:** *"Adaptation to Climate and Other Changes"* (1:30 PM – 4:30 PM)
	Coffee Break (4:30 PM – 5:00 PM)	**Panel Discussion:** "Bridging Perspectives" **Closure** (4:30 PM – 6:00 PM)	
Registration (6:00 PM – 8:00 PM)	**Session 3:** *"How to Build a More Comprehensive Educational Experience"* (5:00 PM – 6:30 PM)	**Workshop Adjourns**	
	Social Mixer (6:30 PM – 9:00 PM)		

THE UNIVERSITY OF ARIZONA
COLLEGE OF SCIENCE
Biosphere 2

3. SESSION DESCRIPTIONS

3.1. KEYNOTES

KEYNOTE #1 - THE SCIENCES BETWEEN TECHNOLOGY, ECONOMY AND POLITICAL REGULATIONS

Dominique Pestre - *École des hautes études en sciences sociales, EHESS, Paris (France)*

The aim of the talk is to spell out the tensions and synergies between technological development, economic logics and democratic demands. My choice has been to put the question in historical perspective and to conclude by drawing some principles that could underpin a normative attitude. I will do that by looking at key historical moments – around 1800, around 1900, and around 2000 – and try to show changes and continuities. I will then comment on the relationships between contemporary techno-science, expertise, economy and 'civil society' today, and on the multiplicity of social spaces in which assessments are made and decisions taken. Finally, I will become normative and propose some principles for the future.

KEYNOTE #2 - TRANSDISCIPLINARITY IN EDUCATION

Andrew Comrie - *Senior Vice President for Academic Affairs and Provost of The Univ. of Arizona*

The University of Arizona (UofA) has long been a leader in encouraging and enabling inter-disciplinarity and multi-disciplinarity in both research and education. Transdisciplinarity, by attempting to properly involve all relevant parties, seeks to improve our ability to provide useful solutions for difficult societal problems. The question is how best to provide a University environment that nurtures and supports the development of transdisciplinary thinking in its students. I will discuss some of my experiences with the UofA system and engage in a discussion of how the University experience can be improved.

3.2. SESSION DESCRIPTIONS

☞ Session 1A – Poster Presentations

Convened by *Maria Sans-Fuentes and Christelle Feliciano (Univ. of Arizona), Murielle Coeurdray (UMI iGLOBES, CNRS), and Laszlo Hayde (UNESCO-IHE).*

Each participant was invited to present a poster related to the subjects of the sessions. (See section 4).

☞ Session 1B - Presentation of SWAN–book data viewer

University of Seville & NIGGG

The viewer is designed to disseminate the spatial data obtained from the authors of the chapters through their research. The tool is developed based on open source software. It allows users to visualize and interact with the spatial data. The web-based GIS application provides functions necessary to convey environmental and social data to experts and non-experts. The swing panel comprises basic and specific layers, designed to display specific information about Tucson Basin area. It could serve as a communication tool between the stakeholders, potential readers and the researchers.

☞ Session 2 - Open knowledge and transdisciplinarity in the era of big data: what lessons for water governance?

Convened by *Violeta Cabello, Leandro del Moral and Nuria Hernández-Mora (Universidad de Sevilla), Monica Ramirez-Andreotta (Univ. of Arizona)*

The term “open knowledge” is used in the title of this international conference and serves as guiding conceptual thread for its discussions. As is often the case when a new boundary concept emerges, it is used in a variety of ways by different fields and areas of work, whether it be government, scientific research, business development and accountability, and therefore has different meanings and understandings. The Open Knowledge Foundation (OKF) defines open knowledge as “any content, information or data that people are free to use, re-use and redistribute - without any legal, technological or social restriction”, specifying that “open knowledge is what open data becomes when it’s useful, usable and used” (*www.okfn.org*). In this conference, open knowledge is understood as the conceptual framework that contributes to the erosion of barriers among disciplinary academic knowledge generation (commonly known as interdisciplinarity), and between the academic and non-academic worlds (commonly known as transdisciplinarity). This first plenary session will tackle some of the different meanings of the concept, attempting to build bridges or at least dialogue among them:

i. Open knowledge as the attempt to make information and knowledge available to all in order to improve accountability and governance;

ii. Open knowledge as the process of building bridges and breaking barriers between scientific disciplines;

iii. Open knowledge understood as the efforts currently underway to break down boundaries between science and society, to increase public participation in scientific research as undertaken in the growing field of citizen science.

The three talks in this session will address some of the following questions:

- How are ICTs influencing means of producing, sharing and disseminating data and information about water management? Are these changes improving transparency and accountability of water administrations? Are they generating opportunities for a more leveled, equal and fair public participation in decisions over water decision?
- Which opportunities does citizen science offer for hydrology and water resources research? Can citizen science contribute to improve information and public participation in water management? What are the implications and challenges associated to engaging citizens in water-related data collection?
- Why does water governance research require transdisciplinary approaches? How can transdisciplinarity contribute to water governance? Which are the main interdisciplinary and transdisciplinary experiences that have emerged in water resources management and research during the past few years? Are ICTs and citizen science playing a significant role in the development of transdisciplinarity? What challenges are they facing and how are they working to overcome them?

Session Structure

1:30 Talk 1: Data, information and knowledge for water governance: a summary of lessons from two years of research.

Violeta Cabello, Leandro del Moral, Nuria Hernández-Mora, Belén Pedregal & Natalia Limones. Dept. of Human Geography, Universidad de Sevilla, Spain

2:00 Talk 2: Citizen Science and water resources management: Potential for transdisciplinary research

Wouter Buytaert – Imperial College London

2:30 Talk 3: Socio-Environmental Synthesis for Water Governance

Jampel Dell'Angelo – Nat. Socio-Env. Synthesis Center, U Maryland

3:00 Three Breakout Groups:

Group 1: Data, information and knowledge for water governance: a summary of lessons from two years of research

Facilitator Leandro del Moral; **Expert** Violetta Cabello

Discussion questions:

- How are ICTs influencing means of producing, sharing and disseminating data and information about water management?
- Are these changes improving transparency and accountability of water administrations?
- Are they generating opportunities for a more leveled, equal and fair public participation in decisions over water decision?

Group 2: Citizen science and water resources management: Potential for transdisciplinary research

Facilitator Monica Ramirez-Andreotta; **Expert** Wouter Buytaert

Discussion questions:

- How are new monitoring technologies changing the availability of data on water resources?
- What is the optimal level of complementarity and redundancy between formal and informal data collection activities?
- How can citizen science generated data be converted into actionable knowledge?

Group 3: Socio-Environmental Synthesis for Water Governance

Facilitator Nuria Hernández-Mora; **Expert** Jampel Dell'Angelo

Discussion questions:

- How do you integrate data from different (and often conflicting) scales and dimensions?
- How to take into account the politics of water in socio-environmental synthesis?
- What are the biggest roadblocks to translate SE synthesis in actionable outcomes in the field of water governance?

4:00 Reconvene and share results (Adjourn at 4:30)

Abstracts of the Talks

#Talk 1. Data, information and knowledge for water governance: A summary of lessons from two years of research

Violeta Cabello, Leandro del Moral and Nuria Hernández-Mora - *Dept. of Human Geography, Universidad de Sevilla*

In the context of the SWAN project, the USE team has used a transdisciplinary approach to water governance research, building on team members' various backgrounds and research interests and on their experience as active participants in Foundation for a New Water Culture's (*www.fnca.eu*) citizen-science network for water policy analysis. Using this approach, we have looked at evolving data needs to inform decisions over water resources and risk management. It soon became apparent that information requirements for natural resources management are influenced by the emergence of the networked society. From a technological perspective, these influences derive from the ever-expanding possibilities provided by polycentric and changing sources of information generation, the rapid development of earth observation technologies and the existence of different avenues for sharing and disseminating data and information. From a socio-political standpoint, the implementation of policies that encourage the standardization and reutilization of publicly produced data and protect the right to information of interested parties, together with growing social demands for information and transparency, also expand the requirements on data producers and managers. However, to what extent the improvement in

the access to water data and information leads to a more leveled public participation in water decision-making is still a question open to debate. Results from this work have been published both in a *SWAN project Deliverable* as well as in a special issue published in *Water Alternatives in June 2015*. We will summarize our experience and lessons learned during 4 years of work and scientific research.

#Talk 2. Citizen science and water resources management: Potential for transdisciplinary research

Wouter Buytaert – *Imperial College London*

The field of citizen science has rapidly developed in recent years, as demonstrated by the recent creation of the *Citizen Science Association*, a "community of practice" that involves organizations, scientists, practitioners and people involved in the participation of the public in scientific research. In the field of water resources management, rapid growth of remote sensing technologies, GIS mapping possibilities, the use of smartphones, is opening new possibilities for citizen involvement in the various stages of hydrologic data collection, processing and generation of information and knowledge, development of management plans and implementation, follow up and evaluation of policies and plans. This session aims to review the state of "citizen science in a hydrological context, exploring the potential of citizen science to complement more traditional ways of scientific data collection and knowledge generation for hydrological sciences and water resources management" (*Buytaert et al. 2014*). It will also analyze the implications of these developments for improved water governance.

#Talk 3. Title: Socio-Environmental Synthesis for Water Governance

Jampel Dell'Angelo – *Nat. Socio-Env. Synth. Ctr. (SESYNC) – Univ. of Maryland*

Water governance is a field that necessarily entails an interdisciplinary approach. The complex, multidimensional, and applied nature of this field calls for the decisive overcoming of disciplinary barriers. As such, socio-environmental synthesis is an approach that is particularly adequate. At SESYNC we focus on "synthesis" to produce fundamental knowledge about co-dependent human and natural systems. Synthesis brings together existing but disparate data, methods, theories, and tools in new and perhaps unexpected ways to reveal relationships or to generate novel insights. This type of research, based on intensive interdisciplinary collaboration, requires

large volumes of diverse data that are difficult to collect and integrate, as well as multiple methods and frameworks from different theoretical. This talk aims at reviewing new practices of interdisciplinary socio-environmental research and highlight the role that they play in water governance.

☞ **Session 3 - How to Build a More Comprehensive Educational Experience**

Convened by *Chloe Fandel, Susan Harris, Hoshin Gupta and Chris Scott (Univ. of Arizona), and N Hernandez-Mora (Univ. of Seville)*

The three pillars of a comprehensive educational experience can be said to be disciplinary learning, practical experience (e.g., research) and transdisciplinary perspective (i.e., context). Arguably, we in academia do a reasonable job with the first two, but could a much better job integrating in the third. During the months leading up to this workshop a group of students participating in the SWAN project organized and conducted a hands-on workshop open to students (from all disciplines) who were interested in strengthening their ability to work on complex problems in transdisciplinary teams that can produce solutions and make a difference. The goal was to co-create the methodology necessary for a successful transdisciplinary study. On the Monday prior to this conference, the students convened at Biosphere 2 for a full day of interaction. During this session, the students will report on their experience/findings/conclusions and moderate an open discussion on the topic.

* Note: Keynote Talk on Day Two (Prof. Comrie) was also devoted to this issue.

☞ **Session 4 - Water Management in Tucson: Collaborative Research to Understand the Challenges of the Future**

Convened by *Aleix Serrat-Capdevila (UA Dept. of Hydrology and Water Resources), Ed Curley (former Pima County Regional Wastewater Reclamation Dept.), Claire Zucker (UA Water Sustainability Program)*

The Tucson Basin has a continuing history of economic and population growth over the last half century that has resulted in significant depletion of the regional aquifer. Today, Tucson is the recipient of water transfers from the Colorado River. It has a complex groundwater storage and recovery system, and an associated credit system. The last natural riparian areas are however

still in danger, and future projections estimate water resources will not be enough to cover growing demands.

This session will focus on current and emerging water issues in the Tucson area, as a context with transdisciplinary challenges related to its continuous urban sprawl, economic growth and its balancing act with limited natural resources. This session will start with each keynote speaker providing their perspective on the current status of water resources and water policy in Pima County, on the following issues:

1- What institutional issues are critical now to deal with the Southwest water drought as well as the impacts of climate change?

2- What research is needed for the current programs to deal with water scarcity (water reuse, water credits, etc.) in order improve the availability of water resources?

3- How could water stakeholders collaborate with the academic community to create new opportunities and perspectives through water resource analysis and research?

Session Structure

Introduction (10 min)*:* Aleix Serrat-Capdevila

Goals of the session, structure and participant responsibilities

Background of the Tucson Case Study

Keynote presentations (50 min)

CH Huckelberry - Pima County Administrator: The Challenges of Water Conservation in Southern Arizona

Franck Poupeau – Director UMI/GLOBES: Presentation of the book “Water Bankruptcy I the Land of Plenty”

Breakout groups (110 min, with 10 min coffee break)

Breakout groups will allow participants to review and discuss the keynote speaker comments along with the research questions and policy issues previously identified by the SWAN students to determine what issues and specific challenges are deemed by each group to be the most critical in managing water resources in a time of scarcity.

(a) Participants divide into equal- sized groups and introduce themselves to their group.

(Groups will be pre-designated to focus on specific management topics such as reuse/quality, water for the environment, laws and regulations.) Each group will have its own facilitator and recorder (10 min).

(b) All groups are briefed on the research project findings of the Tucson case study (abstracts will be sent each participant in advance of the session) (15 min).

(c) Groups discuss keynote remarks and student findings to arrive at a (short) list of critical issues for each topic that need to be resolved to achieve a secure, sustainable water future in the Basin (20 min).

(d) Groups will then develop a research agenda to provide more information or clarity on the issues Identified in (c) above (30 min).

(e) Groups will then present their lists of issues and the corresponding research projects to the entire group for comparison and discussion. Recorders will capture all issue lists and research projects for publication and distribution to participants, member universities and stakeholders and for inclusion in the final SWAN report (25 min).

☞ **Session 5 - Water, Energy and Food**

Convened by *Robert Varady (UA Udall Center for Studies in Public Policy), Christopher Scott (UA Udall Center and School of Geography and Development)*

The purpose of the session is to motivate interest in participation in a discussion of the water-energy-food security nexus. These three sectors are closely and inextricably interlinked at multiple levels and they are key to assuring the well being of humans and the environment. Growing research and outreach attention to this 'nexus' focuses on crucial connections at the resource level. Yet comprehensive and integrative approaches to human security in terms of management and policy, and the degree to which these are embedded in broader political processes, have only begun to emerge. This session explores the nexus and examines its conceptual and operational innovations—as well as its limitations. The session will include discussion of such relevant topics as Integrated Water Resources Management (IWRM), resource governance, demand management, and "soft-path" approaches to management of water, energy, and food resources.

Participants will address a number of questions, including:

- What are the economic implications of managing the nexus as a unit instead of piecewise?
- How can subjects, each requiring distinct expertise, be studied and managed in an effective, yet interdisciplinary manner?
- What are the socio-environmental conditions for effective application of the nexus approach to resource management?
- What are some critiques of the nexus approach?

Session Structure

The session will take the form of a science-policy dialogue, with short (10-Minute) presentations by invited representatives from academia, government, the private sector, and civil society. These will be followed by open discussion among the attendees.

Invited Panel

***Steve Arnquist* -** Assistant to Tucson City Council Member Regina Romero, Tucson

***Katie Bolger* -** Assistant to Tucson City Council Member Paul Cunningham, Tucson

***Alex Cronin* -** Professor, Dept. of Physics, Univ. of Arizona, Tucson

***Laszlo Hayde* –** Sr. Lecturer in Irrig. Engg., UNESCO-IHE Inst. for Water Ed., Delft

Melanie Hingle – Asst. Prof., Dept. of Nutritional Sci., Univ. of Arizona, Tucson

***Mathew Kurian* –** Acad. Officer – Cap. Dev. and Gov., United Nat. Univ., Dresden

***Ralph Marra* –** Sr. Principal, Southwest Water Resources Consulting, LLC, Tucson

***Sallie Marston* -** Professor, School of Geog. & Dev., Univ. of Arizona, Tucson

***Marie Pearthree* -** Central Arizona Project, Phoenix

***Martin Pasqualetti* –** Prof., Geog. Sci. and Urb. Plan., Arizona State Univ., Tempe

***Nicolas Pineda* -** Professor, El Colegio de Sonora, Hermosillo, Sonora, MX

Adriana Zuniga-Teran – Udall Ctr. for Studies in Public Policy, Univ. of Arizona

☞ **Session 6 - Ecosystem Services as a Bridge between Disciplines**

Convened by *Stoyan Nedkov, Mariyana Nikolova, Kremena Boyanova, Rositsa Yaneva, and Tanya Trenkova (Bulgarian Acad. of Sciences; NIGGG-BAS), and T Meixner (UA Dept. of Hydrology and Water Resources)*

The Ecosystem Services (ES) concept helps to make clear the interconnectedness between human and environmental systems. This concept has been strongly integrated within the governance structure of the European Union, resulting in several big initiatives for ES assessment and mapping. In the USA the concept has been adopted by the EPA, USGS, and USDA. In 2015 the White House Administration released a new memorandum directing Federal agencies to factor the value of ES into Federal planning and decision-making. Of course, as with any new concept, it should be approached with caution, and an important issue is how it can best be integrated into education to prepare students and young specialists for the modern day challenges of climate change, resource shortage, contamination, social inequality, and population growth, etc. This session will explore how the ES concept serves to bridge across disciplines in support of management of the human-environmental system. Questions we seek to address include: How do ES tools support decision-making and inform the general public? What applications has the concept found in USA and EU? How does it support the Trans-Atlantic dialogue on environmental issues? Does the ES concept improve communication between disciplines or it is simply a tool for analysis? What are the limitations of the concept and the risks for misleading outputs?

Session Structure

Intro (5 min), **Two Invited talks** (20-30 min) followed by discussion (15 min)

Breakout Discussion groups (45-60 min.) on the topics of:

- ✓ ES and education – preparing the new specialists (Thomas Meixner)
- ✓ ES as bridge between disciplines – natural science perspective (Kremena Boyanova)
- ✓ ES as bridge between disciplines – social science perspective (Darius Semmens)
- ✓ ES as tool to support policy and decision-making (Benjamin Burkhard)
- ✓ ES as a global tool - bridge between continents (Stoyan Nedkov)

Group Reports – 20-30 min, followed by the **Final Discussion**

Abstracts of the Talks

#Talk 1. Humans, nature and ecosystem services – closing the supply-demand gaps

Benjamin Burkhard - *Kiel Univ., Kiel*

Integrative transdisciplinary research of human interactions with their environment requires good knowledge and information about functioning, dynamics, vulnerability and potentials of such complex adaptive systems. Identification and quantification of ecosystem services (ES) and potential threats for their sustainable use, demands innovative research approaches - integrating environmental, social and economic perspectives. ES quantifications on appropriate spatio-temporal scales are needed in order to understand, indicate and map ES stocks, demands and flows. Therefore, it is necessary to acquire knowledge about where and when ES actually are supplied and what is the biodiversity and ecosystem functional base for this provision. Knowledge on ES demand, actual rates of consumption and how these components are interconnected (flows) are needed if ES budgets are to be quantified.

Environmental management and policy-making are expecting robust information about ES supply, demand and flows. Maps and other spatially explicit models allow the assignment of ES supply and demand data to particular landscape units. Building on experience from different case studies (e.g. in Germany, Finland, Bulgaria, SE Asia, Arizona), a methodology (the “ES matrix”) for integrative human-environmental systems analysis has been developed and applied successfully. Aims of the matrix are a) the identification of specific landscape features that are relevant for ES supply, and b) to assess how societal demand for ES drives the political agenda and related land use decisions. Policy interest is very high in Europe, where such targets are promoted within the *EU Biodiversity Strategy 2020*. One target is the development of common ES mapping and assessment (MAES) guidelines. This is, among others, carried out in the *EU Horizon 2020 project ESMERALDA* and in the *ESP*.

#Talk 2. Integrating cultural and biophysical ecosystem service assessment and exploring their incorporation into Federal planning efforts

Darius Semmens - *United States Geological Survey (USGS)*

The task of managing public lands for the maximum benefit of all users requires considering the full range of economic, ecological, and social values when assessing potential trade-offs among the broad array of ecosystem services that these landscapes provide. Until recently, social values

have received little attention relative to their economic and ecological counterparts. Additionally, cultural ecosystem services, with which social values share a particularly close association, have not always been well represented in ecosystem service assessments. To address these deficiencies, Social Values for Ecosystem Services (SolVES; solves.cr.usgs.gov), a geographic information system tool, was developed. SolVES offers capabilities to assess, map, and quantify perceived, nonmarket values that the public ascribes to cultural ecosystem services such as aesthetics and recreation. Several applications of SolVES are explored, including its use for value transfer, scenario analysis, and the integration of results with other types of ecosystem service information.

Pilot studies with the Bureau of Land Management and National Park Service were initiated to explore the feasibility of incorporating ecosystem service information into their planning processes. Results from these studies demonstrate strong potential in some areas, but also highlight important remaining challenges, including data availability, context-relevant assessment methodologies, expertise, and procedural obstacles. Key lessons learned and potential next steps will be presented in light of the recent White House memo directing all Federal agencies to more systematically assess ecosystem services and how they are affected by *decision making*.

☞ **Session 7 - Adaptation to Climate and Other Changes**

Convened by *Xubin Zeng (Director, UA Climate Dynamics and Hydromet. Center); Gregg M. Garfin (Professor, UA School of Natural Resources and the Environment)*

Water resources are needed to sustain human life and human activities (such as food production and energy generation). With population growth and improved standards of living, water resources shortages have increased in many regions of the world. Vulnerabilities to water shortages are further amplified by global warming, associated earlier snowmelt, and more extreme events (such as heatwaves, drought, wildfire, and flooding).

Understanding of the local, regional, and global water cycles is the domain of physical scientists (in hydrology, atmospheric science, and earth system science). To fully address water resources issues requires such physical understanding and, equally important, the insights from social scientists, legal scholars, policymakers, and stakeholders (e.g., local, state, and tribal governments, citizens, farmers and ranchers, and industry).

The goal of this session is to bring together representative relevant partners (physical and social scientists, legal scholars, policymakers, government officials, farmers/ranchers, industry representatives, and citizens) to better understand each other's points of view, to exchange knowledge from different fields on water-related adaptation to climate and other changes, and to bridge perspectives in order to address water challenges and build water resiliency at local and state levels. The specific questions include:

- How will interacting vulnerabilities in water resources management systems change at local and state levels in a warming world?
- What measures (e.g., individual and collaborative actions, local regulations, state legislation, governance systems) are needed to increase the water resiliency at local and state levels, and to anticipate projected changes and interactions between water resources and other systems?
- How can the human factors (e.g., residential, energy, and other industrial water consumption, dam and reservoir operations) be fully included in the future projection of the regional water cycle in earth system models?

Session Structure

Overall goal: Garner insights for workshop proceedings and a publication on multi-sector science-policy-governance nexus issues to improve water resource resiliency.

1:30 **Activity: Setting the Stage** (Two 20-min invited talks focusing on physical and social/policy sciences, followed by Q&A [20 min])

Goals: Introduce key topics related to water resources sustainability, climate change, and adaptation challenges and strategies

2:30 **Activity: Knowledge Exchange** (Two breakout group discussions, with mixed social and physical science participants)

Goals: Identify and prioritize chronic and emerging issues, science and policy challenges, and potential management, governance and regulatory solutions

3:50 **Activity: Report back and further discussion (Adjourn at 4:30)**

Abstracts of the Talks

#Talk 1. Water politics and climate adaptation – path dependency and the challenge of environmental extremes

David L. Feldman - *Professor of Planning, Policy & Design and Political Science; Chair of the Dept. of Planning, Policy and Design, UC Irvine*

The social and policy science of water management has long focused on how polities manage water to cope with weather and climate extremes. Indeed, adjusting to the impacts of drought and flooding – "normal" and recurring events – and averting their most calamitous consequences, have been the principal drivers of water politics since ancient times. This is exemplified by the traditional rise of water policy as a means of altering rivers and harnessing groundwater basins through engineered public works to protect the built-environment, irrigate farms and slake thirsty cities, and generate economic benefits to entire regions.

This presentation will discuss the politics of climate adaptation and water management from the point of departure of "path dependency" – the notion that water politics is shaped by deeply-entrenched social forces which encourage flood abatement, drought alleviation, and provision of water supply through hard engineering approaches. While present-day policy reactions to emerging climatic extremes (i.e., more extreme droughts punctuated by periods of flooding) continue to be shaped by these past practices, especially in the Western U.S. (to take but one example), a newer paradigm has begun to emerge.

This paradigm is characterized by: 1) an emphasis on integrated water management (e.g., wastewater reuse, stormwater harvesting, floodplain management); 2) broader public participation – to facilitate adoption of these and other innovative approaches – and to engage civil society groups in their selection and implementation as a means of climate adaptation (e.g., Australia); and 3) growing reliance on climate-knowledge networks to better influence science-policy partnerships, and boundary-spanning efforts that link local and expert knowledge to cope with, and adapt to, environmental change. Various illustrations will be cited. We conclude by suggesting that the persistence of path-dependent ideological views toward water resource management will continue to insure that climate change remain a hotly contested issue when

advocating for “new paradigm” approaches. This will complicate political consensus and make more difficult the identification of long-term policy solutions.

#Talk 2. Using large-scale models to evaluate the hydrologic impacts of climate change

Bart Nijssen – *Res. Prof., Dept. of Civil and Env. Engineering, U Washington*

Climate change is expected to lead to physical changes in the hydrologic cycle and may have important implications for water management. For example, changes in timing and amount of precipitation will directly change the amount of water at the land surface, while temperature, humidity and radiation changes will affect evapotranspiration. In the American West, these changes will also affect the accumulation and melt of snow, resulting in potentially profound changes in the streamflow hydrograph, which may require adaptations in water management. Other important effects include changes in stream temperature, with consequences for stream ecology and cooling potential for electricity generation, as well as changes in irrigation supply and demand and hence crop production.

Large-scale hydrologic models are important tools for analysis of climate change impacts on the hydrologic cycle. I review the model chain from global climate models via downscaling methods and hydrologic models to water resource and impact models, and discuss strengths and shortcomings of this approach using the Columbia and Colorado basins as examples. The Columbia drains most of the Pacific Northwest and plays an important role in fisheries (salmonids), power generation, and agriculture, and is heavily dependent on seasonal snowmelt. Although much smaller in terms of annual flow, the Colorado is the main source of water for large parts of the American Southwest and southern California and is already over-allocated under current conditions. The differing amounts of man-made storage available in the two river systems result in different questions and adaptive measures in the context of climate change.

☞ **CONFERENCE CLOSURE: Bridging Perspectives (Panel)**

The rapporteurs of each session will make a short presentation (10 minutes) of the main conclusions drawn from their respective sessions. This will be followed by a general discussion. Plans for reporting the workshop findings and conclusions will be discussed.

4. ABSTRACTS OF THE POSTERS

WATER FOR GROWTH IN A WATER SCARCE REGION: A SOCIOLOGICAL PERSPECTIVE ON WATER POLICIES IN THE ARID WEST

Brian O'Neill[1], Joan Cortinas-Munoz[2], Murielle Couerdray[2], Franck Poupeau[2]

1. University of Arizona/UMI-Iglobes; 2. CNRS/UMI iGLOBES

This presentation aims to shed some light on the water scarcity issues that the western United States have been experiencing. Through the historical reconstruction of the water policies in the region, we aim to show that beyond the current drought cycle, water scarcity could be linked to a social history of water policy in the West based on the absence of national planning in terms of water use, in which water is regarded as a vector of economic growth. However, it is also important to understand how local and regional forces defending their economic interests are shaping water. This research, based on secondary information and data, on the archives of the protagonists of the conflicts, and on the gray literature associated with them, constitutes the first part of a broader survey of disputes over water use, as well as the logic that underpins them, and their social effects.

POST-POLITICAL HYDRO-SOCIAL SPACES?: MINING, WATER, AND THE NATIONAL ENVIRONMENTAL POLICY ACT IN SOUTHERN ARIZONA

King, O.

Dept. of Geography and Environmental Mgmt. Univ. of the West of England

This poster outlines the preliminary empirical findings and discussions arising from doctoral research on the implications of the National Environmental Policy Act (NEPA) and related legislation for mining and competing water uses in southern Arizona. Focussing on the contested spaces of public engagement and decision making created by the enactment of NEPA, this research builds on recent debates within geography surrounding 'the political', contributing to perspectives on the consensual or coercive means by which antagonistic interests are reconciled toward policy decisions. The NEPA impact assessment (IA) process for the proposed Rosemont Copper Project - an open cast copper mine on National Forest land in the Santa Rita Moutains, near Tucson - has attracted an exceptionally high level of interest, from the local public to congressional representatives. Archival research and interviews with engaged actors across multiple levels of the state, business and members of the public

highlights how: (1) loose NEPA guidance on the IA process allows relations between the lead agency and the mining company which compromise the democratization of the decision-making process; (2) relations of power between institutional actors and political figures are influential in the former's actions in relation to the issue at hand; and (3) actors step outside of official spaces of engagement, forming mutually beneficial relations in order to effect greater influence upon the decision-making process through alternate means.

ROSEMONT MINE PROJECT: FROM GLOBAL TO LOCAL PERSPECTIVES

Le Gouill, Claude, Boyer, A-L

OHMI Pima County. National Center for Scientic Research. Univ. of Arizona

Known as the “copper state” since the early 20th century, Arizona has a long mining tradition. However, in the 1970s the world copper economy shifted to the South, in particular Latin America, while at the same time the North developed new environmental standards. One of these standards, the National Environmental Protection Act (NEPA) of 1969 in the United States, marked a turning point nationally, but also globally, as it inspired reform in other countries. In this context, the traditional disputes between mining companies and workers have come to be replaced by socio-environmental conflicts, revolving around the implementation of extractive projects.

The case of the proposed Rosemont Mine in Pima County, 50km South from Tucson in Arizona, is particularly revealing regarding the re-composition of the stakes around mining issues. In the local, semi-arid context characterized by strong pressure on water resources, the mining project developed by the company Augusta, and then by HudBay, is perceived by the resident populations as a threat to their resources, as well as for its impact on biodiversity and tourism in the region. In contrast, the project is defended by local economic interests, which see an opportunity for an economic boost. Finally, HudBay justifies this project on behalf of “sustainable mining” and “technological developments,” allowing for less impact on the environment and minimum water consumption.

The analysis of the participation process around the Rosemont project, implemented under the NEPA, has shown the limits of a participatory method, both in number of participants, and in the consideration of its results. It sets down real questions about the process of regulation on socio-environmental conflicts, whose purpose seems to be based more on lobbying strategies at different levels of government and tensions for the control of development strategies.

ADAPTATION OF BULGARIAN WATER SECTOR TO CLIMATE CHANGE EXTREMES

Nikolova, M

Dept. Geog. Nat. Inst. of Geophysics, Geodesy and Geog., Bulgarian Acad. of Sciences

Extreme weather events and the resulting hydro-climatic disasters have increased in frequency and intensity in recent decades, confirming trends outlined in the Fourth and Fifth IPCC reports on the increased susceptibility of Southeast Europe to drought, extreme temperatures, heat waves, and floods. Currently, climate change in the region is most apparent in the frequency and intensity of climate extremes, specifically in temperature and precipitation. These changes may significantly affect the water sector in Bulgaria by the end of this century.

The long-term strategic objective of the water sector in Bulgaria is to ensure sustainable use of water resources and to secure the future needs for water of the population, economy and aquatic ecosystems. The water sector operates in three main business areas: plumbing (supply, drainage and sanitation), irrigation (irrigation, drainage and protection from the harmful effects of water) and hydropower systems and equipment (dams and hydropower facilities). The operation of each one of these systems depends on the availability, quantity, and quality of water.

This paper analyzes the impact and sensitivity of the Bulgarian water sector to climate change and assesses the sector's vulnerability index. The results show that the water sector in Bulgaria is characterized by higher sensitivity and vulnerability toward changes in water quantity and quality and to climate-related extremes such as drought and floods. The Climate Change Vulnerability Index describes the sector as moderately vulnerable to climate change over the 2016 – 2035 time horizon. Some adaptation measures are proposed in respect of these results. The need of better integration between Water Framework Directive, Sendai Framework for Disaster Risk Reduction (SFDRR) 2015-2030 and EU Strategy for adaptation to climate change (2013) are discussed.

POTENTIAL IMPACTS OF THE DEVELOPING PHOENIX-TUCSON "SUN CORRIDOR" ON REGIONAL CLIMATE

Yang, Z[1], Dominguez, F[2], Gupta, H[3], Zeng, X[1], Norman, L[4]

1. Dept. of Atmospheric Sciences, Univ. of Arizona; 2. Dept. of Atmospheric Science, Univ. of Illinois; 3. Dept. of Hydrology and Water Resources, Univ. of Arizona; 4. U.S. Geological Survey, Western Geographic Science Center, Tucson

Land use and land cover change (LULCC) due to urban expansion alter the surface albedo, heat capacity, and thermal conductivity of the surface. Consequently, the energy balance in urban regions is different from that of natural surfaces. To evaluate the changes in regional climate that could arise due to projected urbanization in the Phoenix-Tucson corridor, Arizona, we applied the coupled WRF-NOAH-UCM (which includes a detailed urban radiation scheme) to this region. Land cover changes were represented using land cover data for 2005 and projections to 2050, and historical North American Regional Reanalysis (NARR) data were used to specify the lateral boundary conditions. Results suggest that temperature changes will be well defined, reflecting the urban heat island (UHI) effect within areas experiencing LULCC. Changes in precipitation are less robust, but seem to indicate reductions in precipitation over the mountainous regions northeast of Phoenix and decreased evening precipitation over the newly-urbanized area.

HYDROLOGIC RESPONSE OF ATMOSPHERIC RIVER EVENTS IN THE SALT AND VERDE RIVER BASINS: CLIMATOLOGY AND POSSIBLE FUTURE CHANGES

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1. Dept. of Atmospheric Sciences, Univ. of Illinois; 2. United States Dept. of Agriculture, Southwest Watershed Research, Tucson

The Salt-Verde River basins in northeastern Arizona are vital sources of fresh water for the greater Phoenix Metropolitan area and for two Tribal reservations that rely on the basin's natural resources for their livelihood. The region is critically dependent on winter precipitation for its water resources. In turn, nearly one fourth of the total winter precipitation in these two basins is related to the occurrence of Atmospheric Rivers (ARs). ARs are narrow river-like corridors of water vapor in the atmosphere that bring moisture from the Tropical and Subtropical oceans into Arizona. These ARs are also linked to 60% of the most intense storms in the basins and can cause flooding and sometimes turbid waters that are not treatable for human consumption.

Furthermore, the character of ARs is projected to change significantly in the future as warmer temperatures increase, the water holding capacity of the atmosphere will also increase and consequently change the amount of water carried by ARs.

Despite our increasing understanding of the atmospheric processes that lead to ARs in Arizona, many lingering questions remain on the hydrologic impacts of ARs and their role in replenishing reservoirs, maintaining natural ecosystem health, flooding and drought. For example, how is the frequency and intensity of ARs linked to flooding events and drought alleviation periods in the basin? The overarching goal of this work is to understand the hydrological impacts of ARs in the Salt-Verde basins and evaluate how these impacts could potentially change in a warmer climate. The results of this work will be specifically tailored to address the concerns and needs of natural resource managers in the region and Native American tribes.

QUANTIFICATION OF WATER-RELATED ECOSYSTEM SERVICES IN THE UPPER SANTA CRUZ WATERSHED

Kremena Boyanova[1,2,3], Rewati Niraula[4], Francina Dominguez[5], Hoshin Gupta[4], Stoyan Nedkov[3]

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The ongoing drought in the Southwestern United States places pressure on both scientists and practitioners to find new solutions to water-related issues. In the state of Arizona, this situation requires that the present state of the ecosystems and natural resources be re-evaluated to assess their capacity to sustain the future flow of Ecosystem Services (ES) to society. In this poster, we present an investigation of the influence of local land use practices on the water cycle, and the consequent impact on the supply of Water-Related Ecosystem Services (WRES) that can provide support for water and land management and decision-making in areas experiencing water scarcity.

Our study focuses on the Upper Santa Cruz watershed located mainly in southern Arizona but with a small portion in the Sonora region of northern Mexico. We propose a methodology for spatially explicit quantification and evaluation of the WRES within the watershed, and use the Soil and Water Assessment Tool (SWAT) hydrological model to derive a set of hydrological indicators from model simulation for the period 1987-2006. Being a water-limited region, the

vast majority (approximately 87%) of the incoming precipitation water leaves the system as evapotranspiration.

The different land use types within the watershed influence the hydrological cycle and, thereby, the supply of WRES. We assess and map impacts by analyzing the average annual values of the hydrological variables for each land use type. We highlight the importance of forested lands (evergreen forests and forested wetlands - approximately 15% of the watershed area) for providing the highest supply of WRES in the region and consequently, the importance of their preservation. Nevertheless, the predominant land use types within the watershed (shrublands, urban areas and grasslands ? approximately 81% of the watershed area) provide the lowest supply of WRES, which significantly decreases the overall supply of WRES at the watershed scale.

QUALITATIVE ASSESSMENT OF THE SUPPLY AND DEMAND OF ECOSYSTEM SERVICES IN THE PANTANO WASH WATERSHED, TUCSON

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Analysis of the services provided by an ecosystem provides important policy-relevant information that improves both the decision making process and the communication with stakeholders. By evaluating the capacity of an ecosystem to deliver goods and services that satisfy human demands, we obtain important information that can inform future strategies and actions in support of sustainable environmental management. Implemented via an expert-based assessment that takes into consideration the natural conditions of the case study, the approach enables a complete investigation into the importance of certain ecosystem services, their availability, and their demand in both time and space.

In this chapter we use survey and interview results linked with land cover/land use datasets and GIS data, to assess and analyze the supply and demand of ecosystem services in the Pantano Wash watershed in Tucson, Arizona. The resulting maps display, in a spatially explicit manner, the distribution of supply and demand of ecosystem services, and highlight mismatches and changes in supply and demand over time.

By adopting the concept of ecosystem services (ES), this work contributes to water planning efforts, and facilitates the optimization of strategies for sustainable management in which a

balance is sought between the provision of natural resources and the demand imposed by a myriad of interests. Moreover, it provides support for cooperative decision making and resource planning, by providing a cogent vision of beneficiary' perceptions regarding the importance of certain ecosystem goods and services.

MAPPING OF EROSION REGULATION ECOSYSTEM SERVICES

Stoyan Nedkov[1], Boris Markov[2], Sofia Kostadinova[2]

1. National Institute of Geophysics, Geodesy and Geography; 2. Faculty of Geography, Sofia Univ.

Ecosystem services are benefits that humans receive from their environment. Soils provide many ecosystem services required to support human well-being. Soil erosion is one of the major and most widespread forms of soil degradation. Erosion and sedimentation are natural processes that contribute to healthy and functioning ecosystems. Acceleration of these processes, has severe consequences. The major impacts are on the topsoil layer destroying the capability of the soil to provide economic or environmental services. By removing the most fertile topsoil, erosion reduces soil productivity and increases the risk of flooding.

This study examines how erosion regulation can be evaluated and mapped. To map the erosion regulation, as an ecosystem service, we use four USLE factors – soil erodibility (K), cover management (C) and slope length and steepness (LS). The map of erosion regulation was obtained by integrating data in a raster based GIS method. Maps of these factors were compiled based on a digital elevation model, soil data and satellite image. Erosion regulation map was generated by GIS-based overlay analysis of these factors. The values of the resulting map ranges from 1 (low capacity) to 5 (high capacity). The results reveal the influence of the factors that decrease the erosion rate. Assessment the ecosystem's capacity to regulate the soil erosion can provide important information for environmental management.

HOW MUCH IS YOUR ECOSYSTEM WORTH? TRANS-DISCIPLINARY SCIENCE-BASED ECOLOGICAL VALUATION IN THE SEMIARID SOUTHWEST

D S Brookshire[1]; D Goodrich[2]; J Thacher[1], C D Broadbent[1], M D Dixon[3], L A Brand[4], K Benedict[1], K Lansey[4], J C Stromberg[5]; S Stewart[4] and M McIntosh[6]

1. Univ. of New Mexico; 2. USDA-ARS, Southwest Watershed Research Center; 3. Univ. of South Dakota; 4. Univ. of Arizona; 5. Arizona State Univ.; 6. Attorney at Law and Bilingual Mediation and Facilitation, NM

Quantifying the value of ecosystem or environmental services is gaining significant interest among numerous natural resource management agencies. An overview of s trans-disciplinary project to quantify the monetary value of traditionally non-market ecosystem services in the semi-arid San Pedro and Rio Grande riparian systems will be presented. In these systems, groundwater, surface water and flood regimes strongly influence the abundance, composition, and structure of riparian vegetation, diversity and abundance of avian populations, and thus the overall quantity and quality of ecosystem services. For efforts to succeed in preserving these systems in light of climatic and anthropogenic changes, a stakeholder community and/or policy makers requires a clear understanding of the management options available and a mechanism to evaluate these options.

One appropriate mechanism is a Decision Support System (DSS). For water management where ecosystem services are part of the decision-making criteria, a DSS should have the capability to evaluate management options through the use of a series of coupled physical and ecological models that generates ecosystems service outputs. These outputs can then be reflected as monetized societal values for purposes of analyzing management options. However, ecosystem service values generally remain unknown relative to market values for goods and services. It is the value of ecosystems services and how they are derived from a broad base of scientific information that is the primary focus of this presentation. A central tenant of our efforts is that ecosystems values are appropriately driven by sound scientific information and thus values and sound science are inextricably linked. In the absence of integrated science information, valuation studies (e.g. choice modeling and contingent valuation methods) typically rely on vague program descriptions and imperfect measures of the change in ecosystem services quality or quantity.

WATER MANAGEMENT AND BIODIVERSITY CONSERVATION: THE ROLE OF BIODIVERSITY IN THE HYDROLOGICAL CYCLE IN TUCSON AREA

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1. Biosphere 2. Univ. of Arizona. Tucson;2. Dept. of Hydrology and Atmospheric Sciences, Univ. of Arizona. Tucson

The increasing aridity projected in in Southwestern North America will have negative impacts on biodiversity. Loss of biodiversity can alter the balance of ecosystems affecting the benefits that humans have from them. Water is a key player in ecosystems and its relationship with biodiversity is also bidirectional: while water is necessary to maintain biodiversity, the water cycle is influenced by fauna and flora.

Most research related to water availability and quality has focused on flora conservation and the role of plants in water retention. When focused on fauna, the attention has been mainly focused on aquatic animals. Little is known about the impact of subterranean fauna and soil-dwelling and burrowing species on the hydrological cycle. This kind of fauna creates a large number of burrows and might be a key player in water dynamics, because these activities can change the permeability of the soil. Changes in permeability of soil have further impacts on surface runoff or water storage in the soil, for example.

Here, we do a review on the knowledge on impacts of biodiversity in the hydrological cycle, mainly focused on burrowing rodents of the desert Southwest, and will identify the gaps in the research conducted in the Southwest. Moreover, we analyze the potential inclusion of this knowledge for water management and biodiversity conservation programs.

THE LIVING RIVER PROJECT-COMMUNITY ENGAGEMENT AND TUCSON'S EFFLUENT DEPENDENT SANTA CRUZ RIVER

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1. Pima County Regional Flood Control District, Tucson; 2. Pima County Office of Sustainability and Conservation, Tucson; 3. Sonoran Institute, Tucson; 4. Pima County Regional Regional Wastewater Reclamation Dept., Tucson

As communities in the Desert Southwest search for optimal use of all water resources, including effluent, stakeholders and decision-makers must be informed of the water resources benefits and ecosystem services provided by effluent in order to determine how to make wise choices for

the community. In Pima County near Tucson, the annual Living River report has sought to track changes in the effluent-dependent reach of the Santa Cruz River using a set of 16 indicators, selected by a technical committee of experts, and displayed in an easy-to-understand, graphically-engaging booklet. These indicators align with ecological features having demonstrated significance to the general public, based on a recent public perception study of this reach sponsored by U. S. Environmental Protection Agency.

The first report provided baseline conditions, while the second report captured dramatic changes following upgrades to the two regional wastewater reclamation facilities, which release effluent to the river resulting in a perennial effluent-dependent reach. These changes included a near-doubling of infiltration volume with a commensurate reduction in effluent flow extent, an increase in the diversity of the macro-invertebrates in the water, an increase in the diversity and extent of fish, and a substantial reduction in odor. Pima County has begun engaging school children in this discussion using the Living River of Words youth poetry and art contest, where children go to the river, engage in science activities and then portray what they have learned in art and poetry. Through these efforts the project team is making our community aware of the ecosystem services and water resources benefits of the effluent-dependent Santa Cruz River so that wise choices can be made.

ASSESSING FEASIBLE OPTIONS FOR SUSTAINABLE WATER RESOURCE USE TO INCREASE RESILIENCE IN A SEMI-ARID ENVIRONMENT. CASE STUDY: TUCSON, ARIZONA, USA

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Historically, the City of Tucson in the Sonoran desert of Southern Arizona has relied almost entirely on groundwater pumping to cover human water demand. Depletion of the aquifer damaged the riparian corridor of the consequently fully effluent-dependent Santa Cruz River. Intensified utilization of reclaimed water for municipal use therefore further threatens aquatic and riparian ecosystems. The current primary water sources for Tucson are Colorado River water and reclaimed water. The Central Arizona Project (CAP) reduced the city's dependence on groundwater, but future supplies of Colorado River water are uncertain due to climate

change and over-allocation. It is projected that water supply will not be sufficient to meet demand of the continuously growing population by 2042.

This research provides, based on the analysis of the present primary water sources, an examination of under-utilized approaches, such as the use of rainwater, stormwater and graywater. Special emphasis was given to their potential to benefit the water balance and provide ecosystem services. The significance of traditional and alternative water supply sources was assessed as well as their use sustainability in order to increase resilience for Tucson as a social- ecological system.

This study is based on analysis of peer-reviewed literature and water management and planning documents. Semi-structured interviews with experts in the field of water management, water policy, hydrology and ecology provided insights on dynamics and perceptions in the water and environmental management community. The research has found that water managers currently perceive little urgency to augment the existing water supply portfolio with locally generated, renewable sources. However, rainwater harvesting, stormwater capture and graywater utilization hold great potential to offset potable water demand for outdoor uses, providing numerous ecosystem services while greening-up the urban environment.

DEVELOPMENT OF A WEB BASED GEOVISUALIZATION APPLICATION FOR THE TUCSON BASIN CASE STUDY AREA USING OPEN SOURCE SOFTWARE

Trenkova, T.

National Institute of Geophysics, Geodesy and Geography, Sofia

Advances in web mapping technologies enabled the generation and use of vast amount of spatial data. First and foremost challenge is the extraction of appropriate information from the excessive data overload. In this respect the needs of web based GIS applications for fast and easy dissemination, display and sharing of spatial information are constantly growing. The work investigates some geovisualization techniques for user-friendly data representation. A framework of different types of data is elaborated related to the utilization of spatial datasets for Tucson Basin area and its surroundings. The prototype is developed to serve as a data-viewer for the stakeholders, showing different insights on the data.

The goal is to provide a comprehensive visualization tool for gaining better understanding from the available spatial data for the case study area. The application enables user to view, natural resources information for specific needs. The approach integrates an open source technologies

for development of web GIS applications and tools serving to disseminate the data through the web. Flexibility, extensibility, interoperability and ease of use of the open source software proves the necessity and benefits of the open source solutions within multi-aspect environments and stimulates the move towards global open knowledge.

GLOBAL CLIMATE MONITOR: GETTING KNOWLEDGE FROM DATA

Limones, N.; Camarillo, J.M.; and V. Cabello

Dept. of Geography, Univ. of Seville

The poster summarizes a study aimed at building a data model and a geo-visualization tool that provides access to global climate data: the Global Climate Monitor Web Viewer. Linked to the monitor, a complete set of climate-environmental indicators that are capable of displaying climate patterns on a global scale that is understandable to any potential user (inside or outside the scientific community) will be built and put into service using the same online application.

The objectives of the work described could be summarized as follows:

- To build an efficient data model and a tool that allows access to complex scientific data, such as global climate data, in order to convey the information appropriately to a larger number of potential users. This objective is justified in the need to generate and share information and knowledge with the public in the current context of a networked society.
- To calculate and serve a complete package of easy-to-understand climate indicators that permit a broad number of users to investigate in depth the global weather patterns.
- To develop a geo-viewer specifically for that global climate data and indicators, the Global Climate Monitor (GCM), that is intended to be continuously improved and extended. The final aim is to create a far-reaching instrument to monitor the global climate behaviour (hence the name "Global Climate Monitor").

The main data that are currently displayed correspond to the CRU TS3.21 version of the Climate Research Unit (Univ. of East Anglia) database, a product that provides data at a spatial resolution of half of a degree in latitude and longitude, spanning from January 1901 to December 2012 on a monthly basis.

WATER BANKRUPTCY IN THE LAND OF PLENTY: STEPS TOWARDS A TRANSATLANTIC AND TRANSDISCIPLINARY ASSESSMENT ON THE NATURE AND CAUSES OF WATER SCARCITY IN SOUTHERN ARIZONA

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The poster presents the outline of a book, arising out of the four-year collaboration within the International Cooperation Project SWAN (Sustainable Water ActioN): Building Research Links between EU and US, granted by the European Commission (FP7-INCOLAB-2011). The book is a concerted effort to explore the interplay between a variety of related scientific disciplines including climatology, hydrology, water management, ecosystem services, societal metabolism, water governance, political ecology and social science unified around the topic of water.

In recent years, many newspapers and specialized books have been emphasizing that the Southwestern US will be facing its most severe “drought” to date. While drought is often presented as a perturbation imposed upon a coupled natural and human system, the resulting water scarcity that is supposed to impact local agriculture and urban areas is more accurately seen as a product of the complex interplay between physical availability, the environment, and human demands and behaviors.

This book proposes and explores the purposely provocative notion of “water bankruptcy” so as to emphasize the socio-economic dimension of water issues in the Southwestern US (an primarily Arizona), between the narratives of growth and the strategies or policies adopted to pursue competing agendas and circumvent the inevitable. A first of its kind, developed through close collaboration of a broad range of natural scientists, social scientists, and resource managers from Europe and United States, this book is a committed step towards the collective elaboration of a transdisciplinary approach to unveiling the inner workings of how water is fought for, allocated and used in the Southwestern US. It produces a critical diagnostic evaluation of water problems in the West, with a particular view to identifying risks for the Tucson, Arizona, area (which is facing continuous urban sprawl and economic growth).

DEVELOPING A FRAMEWORK TO ESTABLISH WATER PRODUCTIVITY TARGETS AND INDICATORS WITH CASE STUDY IN PALESTINE

Laszlo Hayde, Megan Blatchford, Tim Hessels

UNESCO-IHE Institute for Water Education

Many populations around the world are currently facing or approaching physical water scarcity. As a result water is a focus in the United Nations (UN) Millennium Development Goals (MDGs) and will be included in the Sustainable Development Goals (SDGs). An essential part of addressing global water scarcity is improving water productivity as identified in MDG 8 and the requirement of reporting water productivity in SDG 6.4.

This research aims to provide insight into how much land and water management practices that are implementable by the farmer can improve water productivity. To achieve this it aims to complete the process by identifying low and high water productivity areas using remote sensing tools such as SEBAL, and associated land and water management practices, to identify target water productivity values for the selected case study area. This will contribute to the development of a WP target framework that is actionable (by farmers) and adaptable (to location). The water productivity will be estimated using SEBAL, then bright and hot spots will be identified, in an area of homogeneous environmental and climatic conditions, to see if possible bright spots can be translated into water productivity targets. An analysis of some of the different land and water management practices will then be undertaken to identify the key indicators that result in the difference between water productivity in bright and hot spots.

The implications of developing this framework may be to improve water productivity in low performing areas through agronomic and water management practices.

5. CONCLUSIONS OF THE SESSIONS

After the conference we asked to the Conveners to send back a summary on the content of the discussions of each session. The following sections correspond to the summaries of each session.

5.1. Open knowledge and transdisciplinarity in the era of big data: what lessons for water governance?

Summary prepared by: Nuria Hernández-Mora, Leandro del Moral and Violeta Cabello.

Session 1, "*Open knowledge and transdisciplinarity in the era of big data: what lessons for water governance?*" was designed to tackle three different understandings of the concept of open knowledge, all closely related with the notion of inter/transdisciplinarity: (1) open knowledge as the attempt to make information and knowledge widely available to improve accountability and water governance; (2) open knowledge as the effort to break down boundaries between science and society, to articulate scientific knowledge production within the broader process of co-creation of actionable knowledge, as undertaken in the growing field of citizen science; and (3) open knowledge as the process of building bridges and breaking barriers between scientific disciplines.

The session was divided into three parts: a plenary with three presentations that served to set up the context for discussions; three parallel break-out sessions where plenary session speakers and facilitators helped guide the discussion around key questions presented by each of the speakers; and a final plenary session where the main ideas of the break-out discussions were presented by facilitators.

Keynote presentations

Keynote presentations tried to answer some of the following questions:

- How are ICTs influencing means of producing, sharing and disseminating data and information about water management? Are these changes improving transparency and accountability of water administrations? Are they generating opportunities for a more leveled, equal and fair public participation in decisions over water decision?
- What opportunities does citizen science offer for hydrology and water resources research? Can citizen science contribute to improve information and public participation

in water management? What are the implications and challenges associated to engaging citizens in water-related data collection?

- Why does water governance research require transdisciplinary approaches? Which are the main interdisciplinary and transdisciplinary experiences that have emerged in water resources management and research during the past few years? Are ICTs and citizen science playing a significant role in the development of transdisciplinarity? What challenges are they facing and how are they working to overcome them?

"Data, information and knowledge for water governance: a summary of lessons from two years of research", **by Dr. Violeta Cabello from the University of Seville**, presented a summary of the key results of 4 years of research conducted by the University of Seville (USE) research team of the SWAN project.The USE team has used a transdisciplinary approach to water governance research, building on team members' various backgrounds and research interests and on their experience as active participants in the Foundation for a New Water Culture's (www.fnca.eu) citizen-science network for water policy analysis. Using this approach, we looked at evolving data needs to inform decisions over water resources and risk management. It soon became apparent that information requirements for natural resources management are influenced by the emergence of the networked society.

From a technological perspective, these influences derive from the ever-expanding possibilities provided by polycentric and changing sources of information generation, the rapid development of earth observation technologies and the existence of different avenues for sharing and disseminating data and information. However, the extent to which ICTs are facilitating new practices of collaborative and distributed generation of and access to information depends on a variety of factors. Water data are diverse, crowdsourced by networks of actors at different scales, and their development is highly dependent on different governance systems.Our research showed that water data handling is sensitive both technically and politically, especially in transboundary basins. In this sense there are two relevant trends driven by the use of ICTs. On one hand there are significant national and international advances on Right To Information policies, Open Data strategies and interoperability of geospatial information. However, progress on governance of data water at local and regional levels is still often in its infancy, hindered by a variety of factors: closed government cultures, poor quality of data, information overload, privacy legislation and lack of standards. Some important remaining challenges in this field are: (1) the need to develop international standards, with the USA

leading with interoperability standards for all sorts of geographic information beyond hydrological datathrough the Open Geospatial Consortium; (2) the need to adapt institutions to new open data legislation, improve coordination among scales and promote a culture of collaborationin public administrations; and (3) the need to develop procedures and methods for data andinformation quality control.

From a socio-political standpoint, the implementation of policies that encourage the standardization and reutilization of publicly produced data and protect the right to information of interested parties, together with growing social demands for information and transparency, also expand the requirements on data producers and managers. Examples from different countries illustrated how crowdsourcing applications for water-data generation ('citizen-sensing' apps) are being used at all levels for different goals:mApps for improving water supply and sanitation in states with weak administration; 'political apps' with governance goals; participatory geo-webs for activists campaigns; or applications for water-related citizen sciencescience projects.

However, to what extent the improvement in the access to water data and information leads to a more leveled public participation in water decision-making is still a question open to debate.It is clear that ICTs are being appropriated by social actors for political goals in a process that has been termed "technopolitics". Indeed, new forms of social action are enabled by the use of ICTs in water-related conflicts. However, technological uptake as an iterative and interactive process between social dynamics, technological structures and institutional frameworks. In fact, social actors combine different strategies with online and offline toolsdepending on context, scale and goals of the action. While sharing data and information through can enable the development of alternative meanings and narratives, social media can also be seen as tools to consolidate dominant discourses, they do not structurally change the *status quo.* The transformative role of ICTs is more important as geographical and problem scale increase.Furthermore, ICTs clearly help reduce costs of organization and participation thus making activist campaigns more effective.However, without a real political willingness to open up spaces of deliberation where all actors can participate in conditions of equality, ICTs do not alter the basic framework for water policy- making. In essence, then, the potentialities of ICTs as transformative tools are linked to the regeneration of the context within which decisions are made, that is, the democratic process itself.

Dr. Wouter Buytaert of Imperial College-London presented the conference**: "Citizen science and water resources management: Potential for transdisciplinary research".** The

field of citizen science has rapidly developed in recent years, as demonstrated by the recent creation of the Citizen Science Association, a “community of practice” that involves organizations, scientists, practitioners and people involved in the participation of the public in scientific research. In the field of water resources management, rapid growth of remote sensing technologies, GIS mapping possibilities, the use of smartphones, is opening new possibilities for citizen involvement in the various stages of hydrologic data collection, processing and generation of information and knowledge, development of management plans and implementation, follow up and evaluation of policies and plans.

The presentation and subsequent discussion session aimed to review the state of “citizen science in a hydrological context, exploring the potential of citizen science to complement more traditional ways of scientific data collection and knowledge generation for hydrological sciences and water resources management” (Buytaert et al. 2014). It also analyzed the implications of these developments for improved water governance.

In the context of extensive field work in the Andean region of Peru, Dr. Buytaert discussed the role citizen science can play in the struggle to create long-term sustainability in remote regions where data is scarce, populations highly vulnerable and heavily dependent on local ecosystem services. In these contexts citizen science can help maximize local impact of research projects, integrate scientific with local knowledge, and foster sustainable development and poverty reduction.

Dr. Buytaert discussed the process of generation of what he called "actionable knowledge", which starts with the collection of information using ICTs and new institutional dynamics that allows multi-level monitoring, data collection andcitizen science; continuesthrough the processing of that information relying on ICTs and web technologies to allow for knowledge co-creation and integration of heterogeneous data and knowledge using modular and distributed workflow construction, simulation exercises and prediction models; and ends with the provision of that information through de-centralizedcommunication andpolicy supportsystems (visualization tools, participatory scenario building, etc.).

Finally, **Dr. Jampel Dell'Angelo did a presentation on *"Socio-Environmental Synthesis for Water Governance".*** Water governance is a field that necessarily entails an interdisciplinary approach. The complex, multidimensional, and applied nature of this field calls for the decisive

overcoming of disciplinary barriers. As such, socio-environmental synthesis is an approach that is particularly adequate.

The *National Socio-Environmental Synthesis Center (*SESYNC) at the University of Maryland, focuses on "synthesis" to produce fundamental knowledge about co-dependent human and natural systems, he discussed the ability of the synthesis approach to bring together existing but disparate data, methods, theories, and tools in new and perhaps unexpected ways to reveal relationships or to generate novel insights. This type of research, based on intensive interdisciplinary collaboration, requires large volumes of diverse data that are difficult to collect and integrate, as well as multiple methods and frameworks from different theoretical backgrounds. The presentation aimed at reviewing new practices of interdisciplinary socio-environmental research and highlight the role that they play in water governance.

Group Discussion on Open Knowledge and Transdisciplinarity in the Era of big Data

After these keynote presentations, participants broke up into three discussion groups where they discussed the questions proposed by the speakers. Discussions were facilitated by session conveners. Below are the main conclusions of each break out group:

Breakout group 1: "Data, information and knowledge for water governance: a summary of lessons from two years of research"

Facilitator: Leandro del Moral
Expert/sepaker: Violeta Cabello

1. How are ICTs influencing means of producing, sharing and disseminating data and information about water management?

    - From a technological perspective, the proliferation of information and communication technologies (ICTs) has boosted the availability of information, along with its storage, processing and dissemination capacity.
    - However, it is more debatable how they are helping to meet the demands of transparency, open data and the new information needs for water governance
    - Water agencies web sites usually contain basic information not politically sensitive, usually in close formats
    - ICTs can restrict public debates because they reduce vis a vis contacts among people.

2. Are these changes improving transparency and accountability of water administrations?

    - Many countries still have restricted Access to Information policies. Agencies have developed their own strategies to 'by-pass' transparency in information that might compromise their work.
    - Confidentiality practices linked to privacy rights are one of these strategies, enhanced by privatization trends of water supply systems.
    - Sometimes the lack of information in the simple result of the lack of data or poor quality of data; in other occasions, data are not disclosed due to fear of misinterpretation by the public. There is a general belief and narrative that water data and information are difficult to understand by the general public and requires some expertise.
    - Disclosure of water data requires establishing a challenging bridge and negotiation between the political sphere and the technical bureaucracies.

3. Are they generating opportunities for a more leveled, equal and fair public participation in decisions over water?

    - Sharing information and data, a process that ICTs facilitate, is a potentially empowering process that can enable the development of alternative meanings and narratives.
    - Decisions over water are not necessarily based on technical information and therefore the premise that better information leads to better decisions may fall short in real decision-making processes.
    - Better information therefore does not structurally change the status quo but enhances social organization. Indeed we now have better information and sharing capacity than fifteen years ago and there is a trend towards openness.
    - Where a willingness to open information, ICTs can transform data into information, knowledge, new discourses and realities.
    - However, we still encounter that critical decisions remain outside of the public debate.
    - There remain significant challenges to take advantage of the huge opportunities offered by ICTs mostly derived from the structural conditions of existing models of decision-making that result from the erosion of democracy and the public sphere.

- It seems that the potentialities of ICTs as transformative tools are conditioned by the regeneration of the context within which decisions are made, that is, the democratic process itself.

Breakout group 2: " Citizen Science and water resources management: Potential for transdisciplinary research"

Facilitator: Mónica Ramírez-Andreotta
Expert/speaker: Wouter Buytaert

1. How are new monitoring technologies changing the availability of data on water resources?
    - The use of participatory geoweb tools to support the work of social movements is contributing to integrate local knowledge into global advocacy for water justice or to support environmental monitoring efforts such as the IPE's pollution digital maps in China.

2. What is the optimal level of complementarity and redundancy between formal and informal data collection activities?
    - This is still very much an unresolved issue. One of the bottlenecks of a better integration of informal data and local knowledge into the scientific process is the characterisation of such knowledge.
    - Informal data may range from simply localized "traditional" observations, to indigenous knowledge that is hard to capture by traditional scientific methods, and require methods such as grounded theory.

3. How can citizen science generate data transformable into actionable knowledge?
    - Citizen science is often related to data collection, though more radical forms of citizen science may also include joint analysis and integration of very different types of knowledge (including local knowledge).
    - The potential for citizen science to move beyond joint data collection is strongly discipline dependent.
    - The notions of credibility and empowerment are extremely important in the context of citizen science, especially in locations with a weak institutional and/or legal framework.

- How to create impact with citizen science projects is often still an unresolved problem. This is related to finding the "sweet spot" of collaboration, and understand the goals and agendas of the actors involved.

Breakout group 3: "Socio-Environmental Synthesis for Water Governance"

Facilitator: Nuria Hernández-Mora
Expert/speaker: Jampel Dell'Angelo

1. How do you integrate data/information from different (and often conflicting) scales and dimensions?

- Important to distinguish data and information. The process of integration takes place in the transformation of data into useful information for different goals
- There are different integrative modelling and conceptual approaches that can be used to integrate data from different sources, disciplines, scales, etc. The technical aspects of integration are complicated, but potentially solvable.
- The true complexities of a synthesis approach for water governance, lies in:
    - The data you require often does not exist
    - Access to different sources of data is sometimes limited because it is privately held, it is available in formats that are not open, or otherwise not publicly available.
- The way the information is synthesized, processed and presented depends on the end-user. Different end-users have different evidentiary standards, tolerance for risk and uncertainty. Questions such as: What are the consequences of uncertainty? What is acceptable risk? Will influence the methodological approach for the synthesis process.
- How do you make data and information available and accessible? This will depend on the goals of the information being generated. Is the goal to transform individual behavior? Is it to inform/transform policy? Is the goal to enhance more profound political transformation?

2. How can you take into account the politics of water in socio-environmental synthesis?

   - We are concerned with “actionable science”, that is, science that has an impact on society. It can be understood as science that seeks to empower the underrepresented, those that have less power and access. It can be understood as the effort to improve the public’s scientific literacy in order to enhance their ability to influence policy.
   - The difference between “actionable” and “applied” science is important. The first seeks to have a transformative impact (on policy, on the political process, on society, etc…). The second (in contrast to basic science) is the science that seeks to provide answers/solutions to specific well-defined real-world problems.
   - It is important to be aware of the time-scales of decision-making (political decisions) when thinking about data gathering and the generation of information. Information generation can be thought of as a tributary to a river that is the policy making process. It must find windows of opportunity when the data/information can be fed into the process in order to influence the policy outcome
   - Crisis can be seen as windows of opportunity to “democratize” science, make it available to the public. In a situation of crisis (drought, flood) there is a societal and policy demand for scientific information and understanding, and thus an opportunity to provide science that impacts societal perceptions and policy.

3. What are the biggest roadblocks to translate SE synthesis in actionable outcomes in the field of water governance?

   - During the scientific inquiry process it is important to be aware of the time-lines and needs of end-users. Also important to be aware of the organizational incentives in place (tenure track careers, publishing requirements, legal constraints, etc.) that limit the ability to produce “actionable science”
   - Dominant narratives, perceptions of reality, are some of the biggest roadblocks to the translation of scientific information into actionable outcomes
   - Often there is strong institutional resistance to change (institutional path-dependency). Existing predominant perceptions, narratives, rules and regimes are not easy to modify.
   - Science is a source of information that can be adapted to the target audience in order to create alternative narratives and new framings of reality. The creation of alternative

(science-based) narratives, is a tool that has the potential to open windows of opportunity that can influence the policy process.

- Note of caution: it is important to guarantee the independence of science, which is often compromised.

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5.2. How to build a more comprehensive educational experience

Summary prepared by Susan Harris and Chloe Fandel

An important component of Institute for Open Knowledge on Water involves the training of highly skilled physical and social scientists and future managers of the water sector. Together with the University of Arizona, a program will be implemented to train graduate students to recognize the multiple facets of complex problems, work within a transdisciplinary research group and constructively deal with the challenges presented by such projects. To explore the need for such a program and the topics that should be studied, a group of more than twenty students worked through a program designed to address the issues common to transdisciplinary projects such as project definition, project management, project operations and project results. The group met monthly during the fall of 2016 and in a final extended day workshop conducted under the auspices of SWAN in February 2016.

One of the important lessons established by the student group is the need for the use of case studies in the training of transdisciplinarity. In the first monthly session, a set of complex

situations involving a range of physical, social, economic and political were presented to the students and the students were invited to identify the areas of the problem that their respective areas of expertise could study and provide knowledge to the group. The assignment presented a high level of difficulty judging from the responses. In contrast, after four months of discussing the different aspects of transdisciplinary projects, when a new case study was presented to the students at the final workshop, an extended discussion ensued with full participation that encompassed the multiple complexities of the problem. Judging from this experience, an educational program should use case studies to enable students to better identify the range of issues present in complex problem that must be researched and understood to achieve viable results.

Another important conclusions reached by the students was the need for a physical facility in which researchers could periodically meet. Although technology can assist on-going collaboration and communication, virtual meetings do not engender the same communication that results from actual meetings. All meetings held during the fall were plagued with technological problems ranging from speakers not working to videos failing to microphones not transmitting. The failure of technology also appeared in the final session of the February conference. A student who had participated in the fall session but who could not attend the final conference desired to remotely participate in one of the final student sessions. The appropriate communication links could not be established and thus prevented the student's participation.

During the course of the final workshop, four speakers were invited to give talks on specific topics that arose during the fall meetings. A physical scientist discussed uncertainty and a social scientist addressed subjectivity. The combination of the two talks emphasized that physical and social sciences must both grapple with and make judgments resulting from uncertainty and subjectivity. Such a basic recognition of common issues aids in bridging the gaps among the disciplines and generating acceptance of research results by the different disciplines. The other two talks, a talk by a sociologist on surveys and a talk by a political scientist on interacting with policy makers also focused on issues common to the disciplines, i.e., methods to gather reliable data and communicate results so that they can be implemented.

To achieve the overall goal of graduating scientists with the ability to recognize the multiple facets of complex problem, the participants of the student workshop developed a list of essential elements to be included in the proposed curriculum:

1. Discuss and define the components, methodology and goals of transdisciplinarity.

2. Discuss a selection of the papers available in the transdisciplinary literature that identify the spectrum of problems encountered in transdisciplinary research projects.

3. Tackle the difficult problem of enabling the students to understand the methodologies of other disciplines. At this stage, the course would address subjectivity in physical and social science and different types of uncertainty found in research projects and different methods to identify and communicate it.

4. Draw on graduate student knowledge by asking students from each discipline to lead field trips and labs and select guest speakers in their respective area of interest.

4. Teach different methods of communication and education to facilitate interaction among researchers and stakeholders in a transdisciplinary research project.

6. Assign a series of projects or a single major project that will require the students to collaborate on a transdisciplinary project with other students and volunteer stakeholders. Productive dialogue among disciplines and different national scientific cultures that results in true transdisciplinary research can only be realized by engaging in specific research project(s).

5.3. Water Management in Tucson: Collaborative Research to Understand the Challenges of the Future

Summary prepared by Brian O'Neill, Joan Cortinas and Murielle Couerdray

In this segment of the Conference, we gathered together a diverse group stakeholders who brought their knowledge and expertise to four separate discussions revolving around the challenges that we all face in our collective water future. Drought and water scarcity is something we all face, but effective and strategic management coupled with an understanding of the complexity of the relationships, be it institutional or among communities, must be understood.

Different improvements and solutions related to the water management, but also the policy challenges in the Tucson Basin have different dimensions. These dimensions are not going to function by themselves; however, all of these dimensions have to be integrated in a multi-faceted approach, either to research, or to practice.**Legal Structure:**

Regarding the rights and regulatory structures linked to water, although they have made the system in Arizona adaptive and flexible, there is a great of work that still has to be done. The

Water rights doctrine of “use it or lose it,” has to be changed. Also, the legal framework needs to be better defined so that uses of water such as urban reuse, by means of wastewater, storm-water, or rainwater harvesting, can be considered. Effluent must be considered as a treated source of water that can be used for human consumption. Also, storage credits and the injection and extraction of water must be researched more closely.

Conceptual Debates:

The second dimension that has been discussed is the need for a conceptual debate around existing discourses on what is “renewable water.” Can we still consider CAP water as a renewable resource? Many groups mentioned the fact that the CAP has a high level of turbidity and so over time, it is conceivable that the ability to recharge and extract such water will create multi-faceted issues.

What is sustainability and is there a market of speculation in Arizona? The laws of Arizona have created this problem through the Assured and Adequate Water Supply Programs and Rules. There is also an issue in creating public policy that revolves around the timeframes in which we think. The Assured Water Supply Rules have a 100 year timeline and yet many of the plans that are made among municipalities are on much shorter timelines and under much stricter regulations, unlike the development community. Within the groups, there was a general consensus that those in the water community could not challenge the community of developers and land barons. In addition, a market based upon speculation revolving around storage credits may be developing in Arizona. Land developers are paying for “paper water” that could be extracted at a later time in times of intense shortage. Additionally, as it relates to issues of the CAGRD, which has had the unintended consequence of allowing new land development projects to extract water excessively based upon the fact that they have paid for water to be recharged in an area that is not hydrologically connected to the extraction site, aquifer imbalances may prove dangerous. Some experts have even suggested that such systems should be heavily reformed. These types of systems may prove useful in the short term, but the long-term risk is that of speculation.

Economic Concerns:

Much of the discourse in the session appeared to revolve around the utility of cost benefit analysis and the possibility of valuing the natural world. Much of the research in this group of

students attempted to address this issue and it was well received by many participants. However, especially the stakeholders and expert managers attending the session expressed many other economic concerns on a practical level. For example, much discussion revolved around the ability and consequences of desalination. The problem of desalination becomes an issue or urban life, because the rates charged to citizens will increase. There was no question that such plants could be built, but, to take the example of Spain, a plant was built and farmers did not pay for the water because the cost was too high. So, there is a component of this in which the plant could be underutilized. Also, we have seen in the United States, that the ability to permit desalination plants can last decades, especially when one considers the environmental considerations. Some participants believed that although some will make biodiversity and ecosystem health arguments against desalination plants, it may be that there are major issues for shallow water areas, thereby making an argument for desalination based on attention being given to physical geography.

Knowledge and Education:

One of the key aspects of both utilities and universities in dealing with our contemporary water problems have to do with extension networks and education, bot to produce new knowledge for research and development, but education also takes the very specific form of “outreach.” So, do people know there is a problem with water? Do they know what the real problems are? How can we improve educational tools for people and make the public understand and reach a more nuanced understanding of the issues that are so imminent?

On a second level, of course, there is the issue of transdcisiplinarity. There is no doubt that this was a transdiciplinary exercise as we had many stakeholders and people with both academic and practical experiences. However, what these people all had in common was an attitude and an agreement that addressing water problems, by using various expertise, could help us understand more than if we acted separately.

5.4. Water, Energy and Food

Summary prepared by Adriana Zuniga Teran

There were 12 panelists in this session. Each panelist talked for 10 minutes about some of the work they do related to water, energy, and/or food (in alphabetical order):

1. Steve Arnquist: Assistant to Tucson City Council Member Regina Romero. He did not attend the session (he was sick).

2. Katie Bolger: Assistant to Tucson City Council Member Paul Cunningham

- Ms. Bolger talked about water-related issues from the local government (City of Tucson) perspective.
- She addressed the water-energy nexus through describing the importance of the Navajo Generating Station (coal powered plant) that supplies 90 percent of the power to the Central Arizona Project (CAP). This station is the largest in Arizona and the third largest in the U.S.
- She also talked about important legislations implemented in Tucson related to water conservation. The conservation emphasis is on how can people reduce their water use. For example, the City of Tucson requires:
    - water harvesting in new development.
    - greywater plumbing
    - a dedicated funding source for conservation embedded in the water bill.

3. Alex Cronin: Professor at the Department of Physics, University of Arizona

- Dr. Cronin talked about solar energy. He described solar energy as interdisciplinary. There are many types of solar power (e.g., water heater, space application
- Between Arizona and New Mexico, there is 2 GW of solar power produced, which is equivalent to 4 percent of the power.
- He described how 50 percent of renewals looks like. He modeled the different energy portfolios (a combination of different types of energy sources) including nuclear, coal, gas, hydro and wind, and solar.
- Solar energy is a great resource but it needs to be combined with other sources because it only works during the day, so there is a gap during the night-time (unless we can develop safe and cheap batteries).
- He also talked about the need to have geographic diversity in solar energy production because sometimes one site can be overcast (cloudy), and other sunny sites can overcome this issue.
- Solar energy is scheduled to ramp up, but there is a need of policy to address problems.

4. Lazlo Hayde: Senior Lecturer in Irrigation Engineering, UNESCO-IHE (Institute for Water Education). Delft, The Netherlands

- Dr. Hayde talked about his book about to come out.
- He also talked about the nexus and some projections. For example, by 2030 we will need 30 percent more water, 40 percent more energy, and 40 percent more food.
- We mostly have relied on engineers to solve these problems, but that is no longer the case.
- He also talked about different planning approaches, where farmers think in a longer time scale, and governments think in a shorter time scale.
- In the future, under drought conditions, we will have to do more with less.
- Among things we can do, there is decentralization (focus on local situations) and education (awareness, knowledge-transfer).
- We have a mission to focus on least developed countries.
- We need a “T” shape education.

5. Melanie Hingle: Assistant Professor, Department of Nutritional Sciences, University of Arizona

- Dr. Hingle talked about her work on health with an emphasis on obesity.
- There is an obesity epidemic in the world, but people are eating unhealthy food.
- She works with the Food Bank on ways to increase the provision of nutritious food.

6. Mathew Kurian: Academic Officer, Capacity Development and Governance, United Nations University. Dresden, Germany

- Dr. Kurian talked about the nexus approach. How the IWRM came before the nexus approach. IWRM was a sort of “dream”, while the nexus approach is living that dream, integrating in action plans.
- He described trade-offs as a fundamental concept. There are three types of trade-offs:
    - Environmental vs. poverty. The IWRM emphasize environmental issues but overlooks people’s lives.
    - Autonomy vs. accountability. Utility companies make their own decisions, and refuse to collaborate.
    - Efficiency vs. equity. How do you distribute risk, profits, and benefits?

- These trade-offs impact education.
- The challenge of the nexus approach is to translate the results to benefits. There are four tools:
    - Data visualization – helps in the decision-making
    - ndices – allow people to work together
    - Scenario analysis – allows to work with uncertainty
    - Benchmarking – mitigating risks.

7. Ralph Marra: Senior Principal, Southwest Water Resources Consulting, LLC. Tucson, AZ

- He talked about scenario planning, and how to make decisions looking into the future (e.g., 50 years) that contains a range of possibilities.
- Scenario planning brings in s diverse set of interests, skills, and expertise.
- The focal point of scenario planning is not what you know, but what you don't know.
- Planning considers space and time dimensions – a lot of uncertainty.
- Scenario planning considers many possible things and adopts to a range to possible futures.
- It allows us to make decisions with imperfect knowledge. We look at what is most important and inevitable.
- This planning approach captures the end points of uncertainty because they pick the scenarios that are most diverse. Then we consider the implications (what can we do about it?).
- It prepositions actions now in response to possible futures.

8. Sallie Marston: Professor, School of Geography & Development, University of Arizona

- Dr. Marston talked about community gardens. These projects can increase capacity building of food production in low income neighborhoods in Tucson.
- In collaboration with the Desert Museum, they created the Mission Garden, where they grow food crops, and native plants.
- Students learn to broadcast trees and this impacts the community. This also reconnects the students with their grandparents.
- She also talked about national datasets – big data.

- Biosphere 2 has the evolution observatory project where 4th and 5th graders participate. They learn how carbon, water and energy move through the landscape.
- They consider the children "scientists in training". The children participate in seed germination trials where they gather data that later is given to the scientists.
- Children are considered the "leaders of tomorrow", who will have to face the challenge of food security.

9. Marie Pearthree

- Assistant General Manager of Business Planning, Central Arizona Project (Phoenix, AZ)
- She talked about her work in the Central Arizona Project and how they are dealing with drought in the region.
- She talks about the strategies followed during drought. She explained the three tiers.
- She showed a bar graph that contained the different uses of water in Arizona, and where the three tiers were placed.
- During persistent drought, the first water use to forgo water supply is "other" and to a lower extent "agriculture". In this tier, all the other uses (e.g., municipal, industrial, Native Nations) still get their share of water.
- During more persistent drought, they go into the second tier, which impacts mostly agriculture production.
- If drought persists then tier 3 gets implemented. In this case, agriculture completely stops and shortage of water affects some municipal and industrial uses.

10. Martin Pasqualetti: Professor, School of Geographical Sciences and Urban Planning, Arizona State University. Tempe, AZ

- Dr. Pasqualetti talked about the water-energy-food nexus. He used Google Earth to show some sites along the U.S. Mexico border, the Imperial Valley.
- He emphasized that Arizona is in a "black hole" because water is imported. Everything is imported.
- Now we have to be more efficient in how we use water, energy, and how we produce food.
- Arizona is the perfect place to be more efficient.

- Imperial Valley is turning land use from agricultural production into solar energy production (he showed solar panels in Google Earth). He proposed to replace agriculture in this area to solar production because it provides benefits including putting water to another use while making land more valuable (less salty). However we have to consider the socio-cultural environment.

11. Nicolas Pineda: Professor, El Colegio de Sonora, Hermosillo, Mexico

- Dr. Pineda talked about the case of desalination in Mexico, focusing in Sonora.
- He explained that desalination has been mostly used at a small scale for tourism. However there are two potential desalination plants in Rosarito, Baja California, and Puerto Peñasco, Sonora. This plants may be binational plants that could provide water for the U.S.
- However, there is not a clear national policy for desalination
- He also talked about the water-energy-food nexus approach, which is a transdisicplinary dialogue.
- We need to have a better understanding of the region (economic and social conditions) in order to improve policy making.

12. Adriana Zuniga-Teran: Postdoctoral Research Associate, Udall Center for Studies in Public Policy, University of Arizona

- Dr. Zuniga talked about her research on neighborhood design and how it affects the use of greenspace, though “walkability.” Greenspace is essential for the functioning of the ecosystems within and beyond cities. The use of greenspace is linked to better health.
- In addition to wellbeing benefits, the use of greenspace is important because if more people use greenspace it is more likely that it will be preserved and managed sustainably.
- During her time as a postdoc, she is still studying greenspace but now through the lens of water security. If designed correctly, greenspace can function as stormwater management infrastructure, in which case it is referred to as green infrastructure.
- Green infrastructure is very important in cities in arid lands because stormwater is directed to these areas and infiltrated into the aquifers. This increases water supply in cities like Tucson that rely on groundwater as their main water supply.

The presentations by panelists were followed by a session of questions and answers. These are some of the topics addressed during the Q&A session:

- "The Law of the River" is the law that manages the allocations of the Colorado River. According to this law, Arizona could go without water from the Colorado under extended drought conditions.
- What educations background do students need to have as future employees? (open question). Answer: Ralph Marra: scenario planning is a tool that comes from corporate management. Teaching scenario planning to students will allow them to use this as a tool.
- For scenario planning considers short vs. long term planning. But for conditions like drought, we don't know if this will be long-term or not. How do you know?

  Answer: Ralph Marra: well you look at your tipping points and try to understand which one will happen first? Put a time-frame in the decision-making. It considers known unknowns, but needs to focus on unknown unknowns – what could we be missing?
- If you are looking for resilience distributed way into decision-making and management, is it feasible? What can help?

  Answer: Alex Croning: From the energy perspective, power plants on tribal lands as an alternative to dams. Do not put all your eggs in the same basket. Look at other supplies. A good skillset to have is to make models (e.g., walkability model), which create new theory that can tackle emerging problems.
- How do you use fossil fuels to transition into more renewable energy sources. One common thread is the lack of sense in politicians (out of logic). There is a disconnect. How do we translate science?

  Answer: You make it profitable to them as well. Both groups can profit (e.g., energy efficiency). It is cheaper to save electricity that to produce more. Good ideas come from unusual places. In California there is the cap & trade, which are market incentives to move away from fossil fuels. We live in a complex world, I say we flip the "T" – education would focus on training students in looking at interconnections – experiential training.

5.5. Ecosystem Services as a Bridge between Disciplines

Summary prepared by: Kremena Boyanova, Stoyan Nedkov, Rositsa Yaneva

The first keynote talk *"Humans, nature and ecosystem services – closing the supply-demand gaps"*, given by Dr. Benjamin Burkhard (Kiel University) presented the main aspects of the ES concept and approaches for mapping and modeling of ecosystem services for policy and decision making. He emphasized that ES are a highly transdisciplinary concept and like the human-environmental systems, it is highly complex. There are many methods and data available and ready for use and policy interest is increasing, but applications and success-stories are needed. Large share of the researchers' efforts are focused on the development of applicable and functional methods for investigation of the ways in which ES flow from the environment to the society and contribute to its well-being. The identification and quantification of ES are crucial during the investigation of ES flows. In order to support the European Union (EU) member states in these efforts, the European Commission initiated the MAES[1,2] (Mapping and Assessment of Ecosystems and their Services) working group and the EU Horizon 2020 project ESMERALDA[3] (Enhancing ecosystem service mapping for policy and decision making). Both initiatives suggest a tiered approach for ES assessment and mapping as follows:

- Tier 1: Expert estimations - rather simple, e.g. land cover-based
- Tier 2: Other indicator data - more complex, e.g. statistics-based
- Tier 3: Empirical model results - complex, e.g. model-based

The speaker provided examples of the application of all three tiers approaches for case studies in Europe, USA, Asia, Australia and Africa.

In order the presented approaches to find application in policy and decision making, a bridge that overcomes the differences in the perceptions between scientist and politicians/decision makers is needed. Nevertheless, many politicians nowadays recognize the key role of scientist for solving modern environmental issues. The United Nations Convention on Biological Diversity[4] (UN CBD) Ecosystem Approach is a global initiative that suggests strategy for the management of land, water and living resources that promotes conservation and sustainable

[1] http://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/pdf/MAESWorkingPaper2013.pdf
[2] http://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/pdf/2ndMAESWorkingPaper.pdf
[3] http://esmeralda-project.eu/
[4] https://www.cbd.int/

use in an equitable way. Its Parties include almost all countries accept USA and South Sudan. The UN CBD defines the 12 Malawi Principles, where Principle 5 addresses clearly the key role of ES: “Conservation of ecosystem structure and functioning, in order to maintain ecosystem services, should be a priority target of the ecosystem approach”. In Europe, the EU Biodiversity Strategy 2020[5] (from 2011) aims to halt the loss of biodiversity and ES in the EU and help stop global biodiversity loss by 2020. It reflects the commitments taken by the EU in 2010 within CBD. It has 6 key targets:

1. Protect species and habitats.
2. Maintain and restore ecosystems.
3. Achieve more sustainable agriculture and forestry.
4. Make fishing more sustainable and seas healthier.
5. Combat invasive alien species.
6. Help stop the loss of global biodiversity.

In 2015 the US government published a memorandum for “Incorporating Natural Infrastructure and Ecosystem Services in Federal Decision- Making”[6]. Key elements of the memorandum include:

- Federal agencies shall incorporate value of green infrastructure and ecosystem services into federal planning and decision making;
- Agencies shall develop and institutionalize policies that promote consideration of ecosystem services in planning, investment, and regulatory contexts;
- A more detailed guidance on integrating ecosystem-service assessments into relevant programs and projects shall be created;
- Ecosystem and community resilience, sustainable use of natural resources, and the recreational value of the Nation’s unique landscapes shall be maintained.

Another global initiative is the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services[7] (IPBES) - an intergovernmental body which assesses the state of biodiversity and of the ecosystem services it provides to society, in response to requests from

[5] http://ec.europa.eu/environment/nature/biodiversity/comm2006/2020.htm
[6] https://www.whitehouse.gov/blog/2015/10/07/incorporating-natural-infrastructure-andecosystem-services-federal-decision-making
[7] http://www.ipbes.net/

decision makers. Its mission is to strengthen the science-policy interface for biodiversity and ecosystem services for the conservation and sustainable use of biodiversity, long-term human well-being and sustainable development.

The presented activities are strongly supported by citizen science and open knowledge initiatives. The MapNat smartphone application[8] can be used for mapping and assessment of personal use of ecosystem services. The collected data is visible for all users and can be used by researchers for analysis. The application is freely available for Android devices, soon for iOS. The journal One Ecosystem – Ecology and Sustainability Data Journal[9] was presented as innovative open knowledge/data sharing platform.

The discussion after the keynote talk focused on the valuation methods applied in EU and USA. It was discussed that the ES accounting just started in EU and there is no agreed uniform monetary unit. The EU is very diverse and no uniform values can successfully be applied. The focus is on the development of uniform methods. In the US large amount of non-monetary valuations were accomplished but there are a lot of challenges for performing monetary valuation. This was recognized as a failure in the US approach due to lacking systematic approach, even if good tools are available. It is impossible to value all the benefits of the ecosystems that come to the society. We should focus on measuring changes and trade-offs. Applying monetary value to the ES was recognized as easy task, but the cultural and personal values are hard to measure and this should be addressed in future. How do you trade-off cultural values? It was recognized that uniform quantification units are very complex and hard to recognize and trade-off assessment is necessary but complicated. Nevertheless, there are many success stories and it would be nice to have an inventory to serve as guidance.

The second keynote talk "*Integrating cultural and biophysical ecosystem service assessment and exploring their incorporation into Federal planning efforts*" was given by Dr. Darius Semmens (USGS). He addressed the topic of ES as bridge between disciplines in the context of transdisciplinary research and presented methods for spatial modeling of cultural ES and an approach for application of ES assessment for quantifying spatial subsidies of migratory species. The integration of the ES concept in Federal policy through the memorandum of the US government from 2015 was once again mentioned in the presentation, in order to underline the institutionalization of the concept in the USA. The speaker presented

[8] http://esmeralda-project.eu/
[9] http://oneecosystem.pensoft.net

the concept of Ecological Endpoints as one that can be supported by its integration within the ES framework. Ecological endpoints are biophysical characteristics or qualities; concrete, tangible, and measurable; and directly, intuitively connected to human well-being (Boyd, 2007). Natural science develops management and models to predict changes in ecological endpoints, while social science weights or places value on ecological endpoints to prioritize management and protection actions. In order to represent this interaction the speaker presented the experience of USGS in the application of the integrated cultural and biophysical ES assessment tool SoLVES[10] (Social Values for Ecosystem Services). SolVES is a GIS tool allowing users to assess, map and quantify social values of biophysical units. Its goal is to augment ES assessments with social value information. The social values are the non-market values perceived by stakeholders for ecosystems and have close correspondence with cultural ES. Often, consideration of social values is lacking relative to ecological and economic values. The tool can also be used for value transfer, future scenario analysis associated with changes in endpoints, integration of results with other types of ES information and incorporation into Federal planning efforts. An example for the application of the tool was presented for a cases study in the Pike San Isabel National Forest, Colorado. The Spatial Subsidy concept was also presented by the speaker as a framework that can be investigated through the application of ES assessments and a transdisciplinary approach. From ecological perspective, the spatial subsidies of migratory species include the ecological support received by an area from the rest of the range (population maintained during the time spent elsewhere) and the ecological support provided to the rest of the range vie the role of the area in maintaining the population (habitat for survival and breeding). From socio-economic perspective, the species provide benefits to human within an area (food, recreation, pest control, pollination, seed dispersal, etc.) and they also provide benefits across migratory range. There are often mismatches between the two perspectives and the places where species provide most benefits to humans may not correspond with the places providing most support to species. This leads to mismatch between ecologically and economically important areas and the net balance between them is the subsidy. The key parameters to quantify spatial subsidies are biophysical (proportional dependence of species) and socio-economic (value of services provided by species). An example of the model application was given for the assessment of the spatial subsidies of the monarch butterflies migration that covers big areas of Canada, USA and Mexico.

[10] http://solves.cr.usgs.gov

The discussion after the keynote talk focused on the presented methods for monetary valuation of the cultural ES provided by the monarch butterflies and the interpretation of the results. The precision of the term “subsidy” was questioned. If the natural habitat of the monarch butterflies in Mexico goes away, the monarch butterflies will also go away. The value that the people in US put on the monarch butterflies should be compensated to the natural area in Mexico for its preservation and conservation. Nevertheless, this would still be a subsidy, not a compensation. Such assessments can be used for choice of management practices and application of Payment for Ecosystem Services (PES) programs. Still, the presented model does not provide the answer what is the trade-off for US people for losing the habitat in US vs. the habitat in Mexico.

Breakout discussion topics

In the beginning of the second part of the session the hosts and the participants agreed on keeping the group together. The discussion was focused on three main topics, as follows:

1. ES and education – preparing the new specialists. Key bullet points of the discussion:

- Is the present job market (inside and outside academia) demanding knowledge about ES? – YES and growing, especially after the institutionalization of the concept.
- Is there demand for knowledge of ES also to the monodisciplinary experts? – YES, more and more often they need at least to understand the concept.
- There is anyway danger of too much integrative approach in education. Environmental management and ES related classes often attract a lot of generalists to sign in. This leads to lack of monodisciplinary knowledge and expertise for solving complex problems, which is often required in ES studies.
- The organization of such classes should be flexible, due to the big diversity in the backgrounds of the students – every discipline can contribute in a unique way to an ES study.
- It was recognized that at the moment there is shortage of ecological economists, while there are a lot of monodisciplinary experts.
- There are tensions in the relationships Academia vs. Government vs. Private sectors which need to be addresses. People are often not evaluated fairly for the position they have. Education should not support such tensions.
- Integration of ES in traditional economics is necessary.

- The key elements of the concept and its application should be addressed already in high schools. At the present, high schoolers are expected to choose a monodisciplinary field for their higher education ("I will study for a doctor/engineer/lawyer/physicist/hydrologist/ climatologist/sociologist/etc.") and multidisciplinary studies are not an option.
- Multidisciplinary studies are not addressed in the society.
- Such education should require from the students to think critically and differently.
- At the moment there are big EU funds that require monodisciplinary experts to work in multidisciplinary projects, which requires a slow process of adaptation among the experts and respectively the educational system.
- Support and attitude from the institutions and stuff towards multi- and trans- disciplinarily is needed.
- In USA the watershed management program supported interdisciplinarity.

2. ES as bridge between disciplines – natural and social science perspective. Key bullet points of the discussion:

- The definition of ecological endpoints requires a bridge between natural scientists and economists. A bridging question between the disciplines is "What data/assessments are needed?" and the two sides should answer to this question interactively – meet on the bridge. Economic valuation for primary ecological endpoints is necessary in decision making and practice.
- Environmentalists and ecologists often use the precautionary principle, while the environmental economists allow decision makers to consider level of risk to take.
- The ES concept deepens the questions scientists ask – the interest is not only to (for example) the riparian area, but what it means and what are its values.
- Terms as triple bottom line accounting and sustainability support interdisciplinary science.
- Historical and behavioral analysis (social science) are significant for understanding the present system and how it may evolve in future.
- Behavior decisions change the system and behavioral sciences are key to understand changes in the system.

3. ES as tool to support policy and decision-making

- ES is a promising concept but real life local application is lacking, in order to proof the concept.
- An inventory of success cases is needed.
- There is a high demand from decision makers the concept to be validated.
- There is an example of success story in the Phoenix area – the applied Urban Green Infrastructure improved the urban human habitat and showed increase in adjacent business sales.
- There are examples in US where conservation was initiated in the past merely to decrease erosion and by this to protect food production. At the present, all other benefits are also recognized – a learning process for the practitioners also.
- The ES concepts helps to proof and document extra benefits of conservation.
- Anyway, benefits of conservation are hard to measure. How do you convince the land owners to conserver? – through monetary compensations.
- Practical obstacles in the decision making process block the ES from making the difference (laws, long procedures).
- The process of integrating the concept in policy and decision making requires multiple steps, but is happening.
- Many national agencies start to incorporate the ES concept in their decision making process (EU, USA, Costa Rica, others)
- The process is bi-directional – top-down (integration in regulations, decision making, laws) and bottom-up (integration in education).

There is also an issue with the term “ecosystem services”. Often the concept is considered to be related to environmentalism or as part of natural sciences, which creates issues for the recognition of its applicability and transdisciplinary character and often even creates resistance from other disciplines and decision makers. Therefore now in EU the term is changed to “nature based solutions”, in order to underline its applicability.

Conclusions

The application and interest of the ES concept is increasing and this process is supported by the institutionalization of the concept in national and international platform (UN CBD, US memorandum, EU Biodiversity Strategy). The concept is promising and deepens the ways in

which we understand the environment and its interactions with the society. It provides ways to measure the benefits from the environment, its value to the people beyond the measurement of environmental variables. Nevertheless, the process is slow and decision makers often require the concept to be validated. An inventory of success stories can provide guidance for the possibilities that the application of the concept provides. Furthermore, the need of multi- and trans- disciplinary thinking should be addressed in the society and the educational system. The ES is a transdisciplinary concept which provides better understanding and knowledge beyond the results of the individual disciplines. Still, there is a risk of generalization of the importance of monodisciplinary knowledge which should be recognized. Often, solving complex problems requires monodisciplinary expertise and transdisciplinary attitude. Such attitude is provided by the ES concept. There is demand for environmental economists to strengthen the links between natural sciences and economics and to increase their applicability for solving modern day environmental issues. The integration of behavioral sciences are key for understanding the changes in the socio-ecological system and should be integrated more in ES and transdisciplinary studies. The concept and the methods for its implementation are still under development and there are many gaps that need to be addressed in future studies, such as identification of unified units, unified methods, systematic approach for assessments, personal and cultural values beyond monetarization, methods for compensation. Nevertheless, there are many existing tools and methods that are alrwady well established and their further development and implementation is a rapidly growing process.

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5.6. Adaptation to Climate and Other Changes

Summary prepared by Gregg Garfin and Xubin Zeng

Session 7, Adaptation to Climate and Other Changes, brought together researchers and practitioners to explore and discuss (a) concerns about the ways in which water management

may be affected by the complex intersection between climate change and other external factors (e.g., population growth), and (b) ideas about the needs for best adapting to projected changes.

The tone for examining these issues was set by keynote talks from the perspectives of political science and hydrological modeling. Before these keynote presentations, everybody did a brief self-introduction to demonstrate the diversity of the participants (social and physical scientists, legal scholars, decision-makers, stakeholders). Following these keynote presentations, participants offered their concerns and ideas about key challenges and potential solutions to chronic and emerging water management issues, given projected changes.

Keynote Presentations in a Nutshell

Water politics and climate adaptation—path dependency and the challenge of environmental extremes, by Dr. David Feldman (University of California, Irvine), examined the ways in which long-established policies and practices, such as rigid institutions and laws, constrain capacity for change, promote perverse incentives that reinforce wasteful and inefficient water uses, and increase the vulnerability of water supplies to climate change.

Through his brief exploration of historical water management practices, Feldman argued that although the model of centralized water governance was able to develop substantial infrastructure and technologies to provide water supplies for agricultural and municipal water uses, practices dependent on strong supply-side solutions are vulnerable to failure in a world in which drought is likely to be more frequent and more severe.

Through examples from California, and Central Asia, Feldman demonstrated the concept of anthropogenic drought (AghaKouchak et al. 2015)—in which the likelihoods of drought and severe drought impacts are greatly increased by profligate, path-dependent and inefficient water uses, based on assumptions of hydroclimatic stationarity. Feldman offered promising alternatives to path-dependence, through water-sensitive politics.

Using examples from Australia, Nigeria, Bangladesh, and California, he demonstrated success in overcoming path dependence through mechanisms, such as distributed water governance, broader public participation in water policy and solutions, development and integration of knowledge networks to inform water management and policy decisions. These and other mechanisms described by Feldman encourage interagency cooperation, incorporation of a wide range of options (a portfolio) to incentivize reduction of water demands, augment supplies, and

spur innovations in water reuse and low-impact development. He stressed the role of boundary organizations, such as watershed councils, agricultural extension, and university-based initiatives to work as honest brokers and trust-builders, with water managers and the public, in order to gain fair and accountable processes and buy-in for adaptively managed, small-scale, incremental solutions that are acceptable to all parties.

Using large-scale models to evaluate the hydrologic impacts of climate change, by Dr. Bart Nijssen (University of Washington), demonstrated close collaboration between water management stakeholders and researchers, to examine the implications of climate change simulations for the Columbia River Basin, and to assess the effects of methodological choices on hydrologic projections. Nijssen described a rich process of collaboration and partnership between researchers and practitioners, based on common interests in the results and science of climate and hydrological modeling, and a common interest in multi-directional learning, through a respectful exchange of knowledge.

He described the multiple uses of water in the Columbia River Basin, including hydropower generation, flood control, irrigation, fisheries, navigation, recreation, and other ecosystem services, and the key stakeholders, including a River Management Joint Operating Committee, tribes, federal, state and local governments, and electric power utilities. The project team worked with representatives of these organizations, in order to identify key concerns, including (a) potential shifts in runoff timing, due to changes in snow hydrology generated by temperature increases, and (b) the effects of modeling choices, such as bias correction and downscaling methods, on the hydrologic projections.

The partners also identified a limited capacity for management agencies to incorporate and assimilate the hundreds of combinations and permutations of multiple emissions scenarios, downscaling methods, and climate and hydrological models. Working together within the parameters identified the stakeholders (e.g., a subset of 10 models and 2 emissions scenarios), and through a well-disciplined schedule of communications, updates, and workshops the partners have been able to make substantial progress toward the goals of co-developing a library of potential futures for stakeholders to examine uncertainties and challenges related to Columbia River Basin system resilience.

Two key elements to successful partnership, identified by Nijssen, are the joint evaluation of research results, and the flexibility of the modeling team to re-run models and explore emerging questions, based on stakeholder requests.

Group Discussion on Adaptation to Climate Change and Other Key Changes

After these keynote presentations, session participants raised their key concerns regarding water resources sustainability, water governance, and challenges and strategies for adapting to a changing climate through two iterations: everybody presented one idea first, followed by each person's synthesis of the ideas in the first round and presentation of his/her revised or new perspectives. The following themes emerged from the rich conversation on these topics:

Challenges and Tensions

- One of the chief concerns raised by physical science participants was a lack of public acceptance of climate change science, and an accompanying need for improved communication of science—by public communications experts—in order to help increase acceptance of science and to bridge science-policy gaps.

- Related to the aforementioned was a concern that humans are essentially short-sighted. Acceptance of this point could serve as an honest and transparent foundation for dialogue to establish a framework for translating uncertainties into opportunities for decision-making actions.

- Similarly, participants raised the point that changes in climate are slow, and that they are superimposed on a highly variable system. This creates the conditions for a cognitive gap, which limits the acceptance of evidence of human-caused climate changes, and hence acceptance of proposed plans in anticipation of projected changes. The analogy of the lack of perception of temperature change by a frog in water that is slowly heated was used to illustrate this cognitive gap.

- A common expression of the lack of trust in scientific evidence for human-caused global-scale climate change is a cleaving to existing paths in water management, which favor historic laws and policies that constrain choices in the face of change.

- This limits the opportunities for institutions to incorporate local needs, knowledge, and understanding to augment policies and practices. One response to these limitations is to develop transparent, open, and fair governance of water management.

- Yet, participants, notably water management practitioners, stressed that they have already experienced climate changes ("climate change is happening now"), and that projected water supply shortages seem plausible. They emphasized that acceptance of these issues is not one of a lack of understanding by water managers, but of the challenge of conveying to the public that climate change management outcomes are not prescribed.

- Moreover, participants highlighted the need to convey uncertainty in ways that are simultaneously scientifically rigorous and easily understood and accepted by stakeholders and the public. Uncertainty is both a communication challenge and an opportunity to explore a range of futures, and flexible options for managing in the face of projected changes.

- While climate change is widely recognized as one of the drivers for water management, it was also recognized that human systems and decision making need to be incorporated into Earth system models to provide the two-way (rather than the current largely one-way) interactions between climate change and water resources.

Solutions and Prospects

- Several participants mentioned that historical water management incorporates an orientation toward approaches (e.g., infrastructure designs) that are resilient to a wide range of conditions. They emphasized that managers need to systematically evaluate whether new approaches are needed, and that they request information to clarify changes in scientific understanding regarding projected changes.

- To move forward, given the aforementioned challenges and tensions, participants recommended approaches that acknowledge the central place of values in resource management decisions. They noted that the development of sufficiently flexible and resilient strategies is contingent on both working with cultural and decision-making norms, and critically questioning these norms.

- Participants also noted that transdisciplinary engagement is central to empowering change-oriented participants in decision-making, and stimulating innovation in local-scale solutions, such as low-impact development, green infrastructure, and enhanced water conservation.

- They noted that engaged science-society processes, such as those described by Nijssen and Feldman, point to the power of collaborative co-developed science and policy to create solutions that are scientifically and operationally rigorous and acceptable to multiple actors in water management decision-making.

- Participants suggested that scientists must embrace new conceptions of how scientific knowledge is considered among many factors in decision-making; these factors include politics, ideologies, and emotions. Transdisciplinary approaches will help scientists break through linear conceptions about the use of science in decision making.

- A combination of new approaches to water governance, along with the flexibility to take advantage of crises in order to move public debate forward, will help change dominant narratives that assume the abundance of water resources to facilitate unlimited population and economic growth. One participant noted that “we are living paycheck to paycheck in terms of ecosystem services,” and in order to provide sufficient water for the environment, we need to (a) develop our abilities to do more with less, (b) to embrace scientific knowledge, and (c) move with confidence when current observations, historical variability, and projected changes align to create the foundation for a believable narrative that motivates changes in operational practices and policies.

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ANNEX 1

CAN WE TALK?

DESIGNING A TRANSDISCIPLINARY EDUCATIONAL EXPERIENCE

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Sustainable Water ActioN

A hands-on training program and workshop hosted at the University of Arizona for researchers from all disciplines interested in strengthening their ability to work on complex problems in transdisciplinary teams that can produce solutions and make a difference.

As part of the International Conference: Open Knowledge – Bridging Perspectives to Address Water Challenges

Thirty graduate and post-graduate researchers are invited to participate in a student-led project to develop a methodology for a successful transdisciplinary study. Participants will each meet once a month for 60 to 90 minutes via teleconference to address specific topics critical to research projects that produce solutions. Over the course of the series of meetings, each group will address six topics that pertain to the design, execution and reporting of a transdisciplinary study. To enable productive discussion, each person will be asked to prepare (prior to each meeting) a brief commentary on the topic to be discussed.

In February, participants will converge in Tucson, AZ for the Open Knowledge International Conference. Selected applicants will receive: travel funding (US only), two nights at Biosphere 2, two nights at the Doubletree Hotel, and at least one meal per day during the conference.

Schedule (subject to change):

September: Launch
- Introduction to transdisciplinarity
- Select first study topic, define facets of the project

October: Project management
- Discuss meeting schedules, format, and rules
- Analyze and contrast leadership and committee structures for optimal results

November: Project definition
- Define study boundaries appropriate to all disciplines
- Define conflicts of interest
- Define methods to coordinate research

December: Project Operations
- Address areas of uncertainty
- Discuss methodologies of each discipline and impact on research
- Analyze roles of stakeholders and researchers and methods to incorporate stakeholders into research process

January: Project Results
- Discuss methods to use knowledge produced during research to further the project
- Identify steps and actions necessary to implement proposed solutions

February: Tucson Conference
- **Student session:** A full day of work and discussion at Biosphere 2. Participants will evaluate results of the training program and apply developed methodology.
- **Main Session**: Two days of panel discussions and talks among American and European researchers aimed at increasing communication and collaborations between natural scientists, social scientists, stakeholders, and citizens to development and implement successful transdisciplinary research projects.

Topics in the Main Session:
- Open knowledge, citizen science, & big data
- Ecosystem services as a bridge between disciplines
- Food-energy-water nexus
- Water management in Tucson
- Adaptation to climate & other changes

ARIZONA CAPACITIES cnrs

DATES & REGISTRATION

Feb. 14th-15th – Student Session – Biosphere 2

Feb. 16th-17th – Main Conference – Tucson, AZ

For more information contact Chloe Fandel (cfandel@email.arizona.edu) or Susan Harris (susanwardharris@email.arizona.edu)

To apply, fill out application form below and return to Maria Sans-Fuentes (sans@email.airzona.edu) before September 5, 2015.

Name:_____

Address:_____

Email address: _____

University: _____

Course of Study/Discipline:_____

Graduate Status: _____ Master's Student _____Ph.D. candidate ____post graduate

Anticipated Date of Graduation: _____

Name of Faculty Member recommending applicant:_____

Email address of Faculty Member: _____

Please include a brief paragraph outlining your interest in this project.

ANNEX 2

Committees

Local Organizing Committee:

- Franck Poupeau (CNRS-iGLOBES/University of Arizona)
- Hoshin Gupta (University of Arizona)
- Maria Sans-Fuentes (CNRS-iGLOBES/University of Arizona)
- Colette Doressoundiram (CNRS-iGLOBES/University of Arizona)
- Xubin Zeng (University of Arizona)
- Aleix Serrat-Capdevila (University of Arizona)
- Chris Scott (University of Arizona)
- Bob Varady (University of Arizona)
- Tom Meixner (University of Arizona)
- Chloe Fandel (University of Arizona)
- Christelle Feliciano (University of Arizona)

International Organizing Committee:

- Nuria Hernandez-Mora (Universidad de Sevilla)
- Leandro del Moral (Universidad de Sevilla)
- Stoyan Nedkov (NIGGG-BAS)
- Laszlo Hayde (UNESCO-IHE)
- Chad Staddon (University of West England, Bristol)
- Juan Valdes (University of Arizona)
- Graciela Schneier (CNRS)

Advisory committee:

- Andrew Comrie (University of Arizona)
- Joaquin Ruiz (University of Arizona)
- Sharon Megdal (University of Arizona)

Student Event Committee:

- Chloe Fandel (University of Arizona)
- Susan Ward Harris (University of Arizona)
- Hoshin Gupta (University of Arizona)
- Christopher Scott (University of Arizona)

ANNEX 3

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