Socio-hydrologic change in the upper Arkavathy catchment, India

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The developing world faces unique challenges in achieving water security as it is disproportionately exposed to stressors such as climate change while also undergoing demographic growth, agricultural intensification and industrialization. Investigative approaches are needed that can inform sound policy development and planning to address the water security challenge in the context of rapid change and data scarcity.
We investigated the ``predictions under change" problem in the Thippagondanahalli (TG Halli) catchment of the Arkavathy sub-basin in South India. River inflows into the TG Halli reservoir have declined since the 1970s, and the reservoir is currently operating at only 20% of its built capacity. The mechanisms responsible for the drying of the river are not understood, resulting in uncoordinated and potentially counter-productive management responses. The objective of this study was to investigate potential explanations of the drying trend and thus obtain predictive insight.
Our approach was then to develop a set of hypotheses of what broad factors might be contributing to drying using available data -- was it declining rainfall, rising temperatures, groundwater pumping, eucalyptus plantations or stream fragmentation? The historical data clearly showed that changes in rainfall and temperature could not explain the sharp declines in streamflow.
Having broadly established that groundwater pumping, stream fragmentation and eucalyptus were responsible for the river drying, the next task was to understand the processes at work and their interaction. To do this we embarked on an intensive three year field study to test various hypotheses including household and farm surveys, focus group discussions, isotopic studies, analysing satellite imagery, borewell camera scans, streamflow and soil moisture sensors, weather stations and a participatory groundwater monitoring programme.
The farmer survey showed clearly that as Bangalore city grew, farmers follow a "go big or quit" strategy. It makes no sense for farmers in nearby rural areas to continue in rainfed agriculture - they were better off either putting their land under eucalyptus and going to work in the city. Farmers who remain in agriculture can only justify it by drilling deep borewells to grow irrigated high-value crops that could be sold in the city or exported. The hydrologic studies showed that the pumping was causing groundwater to decline sharply. The eucalyptus trees were taking up much of the infiltrated water and decreasing recharge. The policy response to declining groundwater was to set up check dams to boost recharge but all this did was to accelerate stream flow decline. Because electricity is free and borewell drilling is relatively affordable, there is no limit on how much water humans are abstracting from the system. The net impact is an increase in ET in the upper catchment over time and a decrease in downstream flows to the reservoir

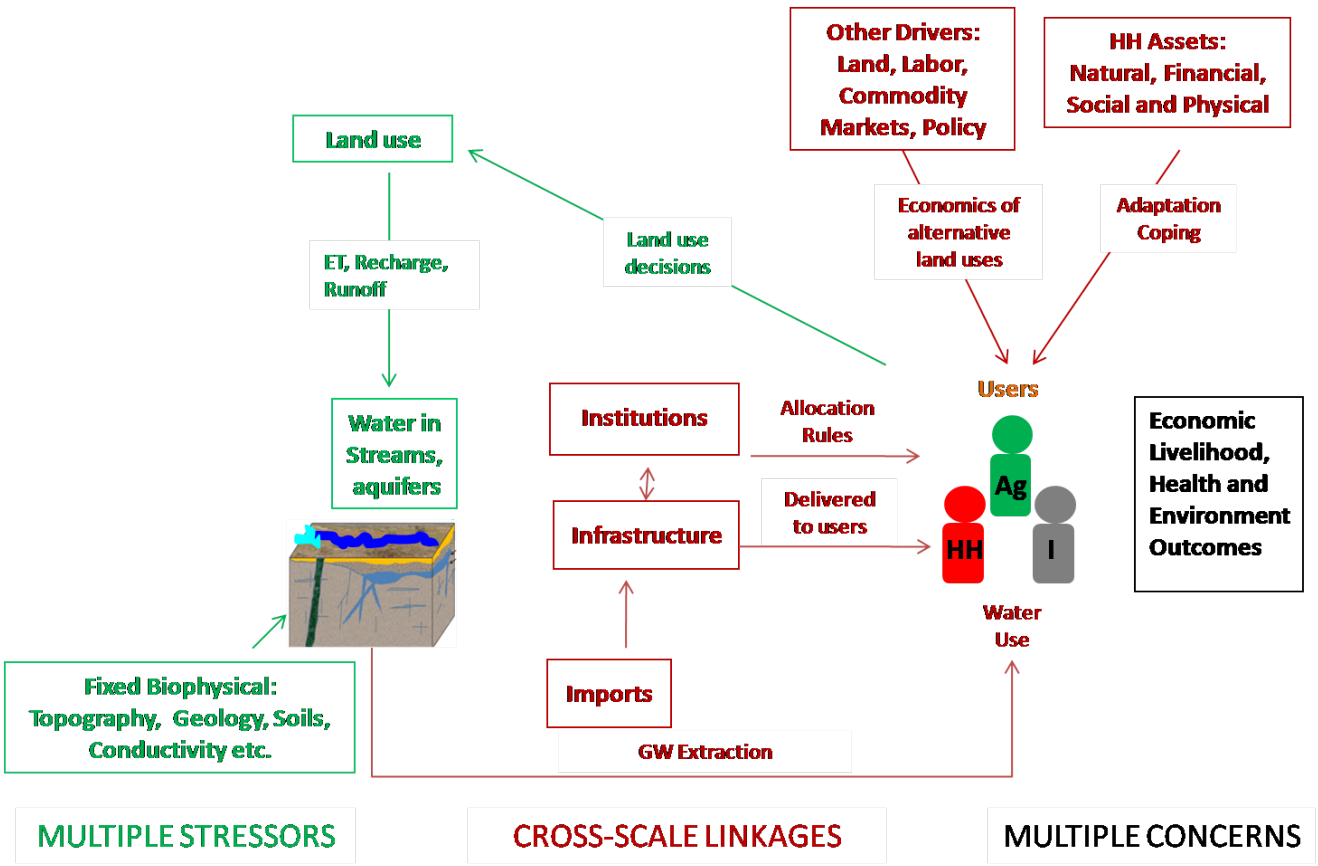
The research led us to conclude, that first humans are both changing the system and in turn responding to environmental change. The impact of urbanisation (an exogeneous driver) was not merely hydrologic in terms of infiltration or ET but a change in land, labour and commodity markets that in turn had severe consequences on the hydrology.

Second, the hard rock geology meant that groundwater storage is limited. In effect the aquifer only acts as a buffer storage (it stores rainfall in wet periods so it can be used in dry periods); overall rainfall remains the limiting factor. t

Third, not only is total use unsustainable it is also inequitable; the water is locally captured by just a handful of large irrigators. But the combination of borewells, eucalyptus and check dams results in an "upstream shift" of the water which has its own basin-level equity implications.

In the long term, the only option (in the absence of inter-basin imports) is to stay within the water resources available through enforceable limits on water abstraction via a water budgeting exercise at both the local and regional scale.

Keywords: socio-hydrology, urbanisation, groundwater, India, check dam, climate



Net anthropogenic nitrogen inputs and their impacts on stream water quality in the upper Yangtze River

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Various human activities influence not only the hydrological cycle but also the nitrogen cycle in a river basin. Nitrogen inputs to the river basin are increasing due to the increasing human activities, and the nitrogen input increasing have caused many water environmental problems. Understanding the interactions between human activities and hydrological processes is important for predicting the changes of water quantity and quality. This research selected the upper Yangtze River basin as the study area, and analyzed spatio-temporal variation of the net anthropogenic nitrogen inputs (NANI). To predict nitrogen inputs into the river and their impacts on river water quality, a distributed hydrological model coupled with the non-point source pollution was developed considering the interactions between human activities and hydrological processes. Based on the simulation results, it analyzed the characteristics of hillslope nitrogen loading and the impact on river water quality. The results obtained in the upper Yangtze River basin demonstrated that the major nitrogen sources were the agricultural fertilizer application, atmospheric nitrogen deposition and food/feed nitrogen input. The high values of NANI were concentrated in Chengdu Plain. Increasing urban area has changed the ways of farming and cultivation in cities and surrounding cities, which resulted in the increasing NANI. The simulated results also showed that annual total nitrogen loading was 1.50 ton/km^2 in the upper Yangtze River basin. The amount of nitrogen loading in July and August took more than 65% of the annual total nitrogen and the export coefficient of nitrogen was 0.26 at Yichang station, which was influenced by both artificial nitrogen inputs and the natural hydrological processes. The nitrogen concentrations in the stream waters are high in the rainy season because of strong interaction of hydrological processes with the human activities.

Keywords: net anthropogenic nitrogen inputs, hydrological processes, human activities, stream water quality, interaction between hydrological processes and human activities

Impact of climate change and human development on future freshwater availability in Africa

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With a constantly growing global population, ensuring a sustainable food production is one of the biggest challenges that humanity is expected to face in the near future. Moreover climate change is adding pressure on our planet; indeed according to the Intergovernmental Panel on Climate Change (IPCC), CO2 emissions will be responsible for changes in temperature and precipitation distribution with unforeseen consequences on freshwater availability for agriculture. Based on the modelling work of the Coupled Model Intercomparison Project (CMIP5), we conduct a systematic analysis of long-term climate forecasts in order to identify and quantify signals of human development on freshwater consumption in the main African river basins. An ensemble of climatic and land variables from CMIP5's outputs - mainly temperature, precipitation, runoff and land cover - for the period 2006-2100 was used to calculate actual evapotranspiration and the evaporative ratio (ratio of actual evapotranspiration to precipitation) through water balance. These parameters were evaluated within the Budyko framework - a hydroclimatic analysis tool that links water availability and energy demand - as obtained from a selection of climate simulations with different emission scenarios to determine potential hydroclimatic change. Some of the those simulations include land cover forecasts, allowing to map out the land use change pathways and discern the relative impact of land and climatic drivers on forthcoming freshwater availability.
By analyzing rose plots for change in Budyko space we found that freshwater availability is changing in a heterogeneous way across the continent in terms of both intensity and directions. Some common patterns emerges across all the models within African basins. In particular, the most serious CMIP5 emission scenario, shows consistent increasing trends of the ratio of potential evapotranspiration to precipitation while less congruous results appear for the evaporative ratio in the model simulations. The first can be explained by the strong dependence of potential evapotranspiration on temperature, which experience an increasing trend due to global CO2 emissions. On the other hand, the evaporative ratio is linked to many complex ocean-land-atmosphere dynamics, which are very sensitive to model components and settings. Directions and magnitudes of such a change in hydroclimatic signals vary from model to model and can be interpreted as evidence of climate change and land use change effects, according to models design characteristics. Considerations about combined climate and land change effect on evapotranspiration is thus deduced by discerning from model land cover components, and the effect on future freshwater use trends is calculated with this methodology.
The applied methodology and results of this study can be a useful tool to bridge the state of the art in climate modelling to climate change mitigation strategies, supporting policy makers to develop sustainable water management and land use change practices.

Keywords: Future freshwater consumption, Budyko framework, Africa

Size and stochasticity in irrigated socio-hydrological systems

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Here we present a systematic study of the relation between the size of socio-hydrological systems and stochastic forcing. In particular, through a stylized theoretical model, we focus on how stochasticity in water availability and taxation interacts with the stochastic behavior of the population within irrigated socio-hydrological systems. Our results indicate the existence of two key population levels for the sustainability of such systems: (i) the critical population size required to keep the system operative--with a smaller population size, the system may self-organize toward a collapse; and (ii) the population threshold at which the incentive to work inside the system equals the incentive to work elsewhere—the system will self-organize toward this level, despite sub-optimal per capita payoff to its population. When subjected to strong stochasticity in water availability or taxation, the system may suffer sharp population drops and irreversibly disintegrate into a system collapse, via a mechanism we dub ‘collapse trap.’ Our theoretical study establishes the basis for further work aiming at understanding the dynamics between size and stochasticity in irrigated systems, which is key for devising mitigation and adaptation measures to ensure their sustainability in the face of increasing and inevitable uncertainty.

Keywords: Coupled natural-human systems, Stochasticity, Agriculture, Regime shift

Hydro-social Metabolism: Scaling of population growth and water use of nations

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Water is important for human life. It is the carrier of nutrients, amongst other things, that control human metabolism. Metabolism, which is a process of transforming energy and materials for work or biomass generation, is one key process that has been hypothesised to control population growth of multiple species as well as flux exchange between species or constituents of an ecosystem. A -1/3 power scaling between population growth rates and rates linked to metabolism such as biomass production or rate of energy consumption has been observed spanning >20 orders of magnitude in body size (from zooplanktons to mammals).

Central hypothesis of this paper is that water flux controls the average human metabolism of nations and hence population growth rates. United Nations population statistics and water use of regions (Africa, Asia, North America, Europe, Australia and Latin America) from 1950 to 2000 at irregular 5 years intervals are used to reveal the power scaling between the two. In addition, strikingly similar inter-temporal dynamics in between industrialized regions (North America, Europe, Australia) and in between less developed regions (Africa, Asia) is found. The dynamics across these two clusters of regions is similar in only one respect. The per capita water use and birth rates in both the clusters of regions follows a trajectory that first sees increasing per capita water use with decreasing birth rates followed by decreasing (or constant in case of Africa and Asia) per capita water use with decreasing birth rates. These trajectories demonstrate path dependency of the co-evolution of water use with population growth on the past and corroborate with increased labor participation of women in the industrialized world and perhaps with post-colonial transition in Africa and Asia.

Nonetheless, at any given point in time, all regions appear to always lie on the -1/3 power law relationship between human water use and population growth rates. This offers support to the second hypothesis of this paper, that the -1/3 power law relationship between nations at any point in time is independent of the temporal co-evolution of water use with population growth.

If the above hypotheses are found to hold valid with finer national scale data at more regular time intervals, this may indicate that humans are no different than non-human primates, other mammals and organisms in being governed by the relationship and that nation states are organisms whose water use and birth rates are constrained by hydro-social metabolism.

Keywords: coupled human-water systems, socio-hydrology, social metabolism, population growth, water use

Commodity flows across spatial scales

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Commodity flows are the spatial and temporal redistribution of goods. Recently, there has been a surge of research in international trade in the scientific literature, primarily due to an interest in the natural resources embodied in the traded commodities (e.g. water, carbon, nutrients). International trade is typically measured annually between countries, but commodity flows occur at many different scales, though data availability at finer temporal and spatial resolutions is typically limiting. Here, we present an empirical analysis of commodity flows in primary units (i.e. mass and value) across three spatial scales: global, national, and village. To do this, we obtain data on international trade, national commodity flows of the United States, and village commodity flows in Alaska. Importantly, we segment the data into food and non-food commodity classes to evaluate the unique features of food flows. We determine the network properties of commodity flows for each spatial scale, finding that node degree distributions are fit by normal distributions, node strength distributions are fit by Weibull distributions, and a power law relationship exists between node degree and strength across scales. A core group of nodes exists in each network. This work sheds light on the scaling properties of commodity flows, indicating some unifying underlying mechanisms and can be used to estimate commodity flows at scales for which empirical information is not available.

Keywords: Commodity flows, Scale, Networks

Asymmetry of agricultural water consumption in arid regions during alternating decadal scale wet and dry periods: explanation using behavioral economics

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Increase of human water consumption for agriculture and consequent degradation of the ecological environment is a common feature in many arid regions. Understanding the driving mechanisms behind this phenomenon is of critical importance for regional sustainable development. In this study, analyses of temporal patterns of human water consumption are carried out in three hyper-arid inland basins, i.e., Aral Sea Basin in Central Asia, and the Tarim and Heihe River Basins in Northwestern China. Multi-decadal time series of hydrological and human consumption data are divided into decadal sequences of wet and dry years. During the wet phases, the greater water availability inspires economic expansion and human water consumption experiences growth at a rate faster than that of incoming water. During the dry phases, however, the expanded economy (e.g., irrigation land expansion in an agriculture-based economy) has been managed to sustain or even to increase production by over-exploitation of water with sophisticated technologies. Inability to reduce human water consumption at a rate commensurate with the decrease of incoming water supply leads to serious ecosystem degradation. This asymmetric human water consumption response of society to decadal scale hydrologic variability can be explained in terms of prospect theory drawn from behavioral economics, which states that people tend to be risk averse when facing gains and show risk preference when facing losses. In the three socio-hydrological case studies, direct economic gain/loss has relatively low value but high certainty when compared to indirect economic loss/gain (such as environmental or sustainability loss/gain), which has high value but with high uncertainty. According to prospect theory, people tend to gain direct economic benefits at the expense of environmental degradation and at the risk of system collapse. The outcomes of this study have major implications for water resources management at long time scales, and in particular calls for increased understanding of human-water system interactions and feedbacks at the decadal time scale.

Keywords: sociohydrology, decadal variability, human water consumption

A behavioral approach to understanding human-water interactions under hydrological variability

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One approach recently proposed for studying the interactions between hydrology and the social components is the use of an interactive interface that allows observations of human decision-making in response to simulated hydrologic events. However, despite its potential to generate empirical data on human-water interactions, such an interactive method involving actual people has been rarely used in the study of socio-hydrology. We suggest that laboratory behavioral experiments, or experimental economics, can be a useful research method that can help bridge this gap. For example, in the field of socio-ecological systems research, behavioral experiments are increasingly being used to study human behavioral response to ecological dynamics. This study showcases a behavioral experiment designed to study human-water interactions in the context of irrigated agriculture. In this experiment, human-subjects are faced with a set of decision problems on collective management of shared irrigation infrastructure in the face of hydrological variability. We generate new hypotheses regarding how humans should learn to anticipate and build adaptive capacity to extreme hydrological variability by comparing the decisions of human-subject groups that participated in the experiment. Our findings suggest that under hydrological stability, groups may be able to perform well without frequent adjustments to their strategy. They can still succeed as long as they tightly coordinate on shared strategies along with active monitoring of their irrigation system and user participation in decision-making. However, such groups may be fragile under hydrological variability. Only the groups that experience active learning, monitoring of irrigation system, and probing of the boundaries of their status-quo strategies are likely to remain resilient under hydrological variability.

Keywords: behavioral experiment, irrigation system, socio-hydrology

Water in a Warming World: Exploring the nexus of Climate Change, Water, and Human Values

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The Portland, Oregon Metro region is faced with rapid urbanization and as the demand for hydrologic ecosystem services increases, so does encroachment into undeveloped upland reaches of the watershed along with the negative environmental and social externalities that ensue. To mitigate this damage, water managers must design source water protection programs that incorporate the negative effects of water quality degradation due increased urbanization and potential adverse effects of climate change. In order to do this water managers must understand water utility ratepayers attitudes and preferences towards source water protection programs and climate change. We investigated customer support, more specifically Willingness-to-Pay (WTP) for source watershed protection programs, environmental values, climate change beliefs, and other policy instruments. The sample was comprised of 466 greater Portland, Oregon area residents. Respondents overwhelmingly indicated support for restriction programs and education programs, with a lack of support for financial assistance programs. Respondents largely distrusted non-profit organizations and federal agencies for implementing effective source watershed protection. Multi-variate analysis revealed that greater trust in local conservation agencies, recognition in the consequences of climate change, sense of place, higher income, and education were strong predictors of greater policy support. Personal values and political affiliation were good indirect predictors of policy support.

Keywords: WTP, CHANS, Climate Change, Watershed Protection

Drought in the Anthropocene: examples from around the world

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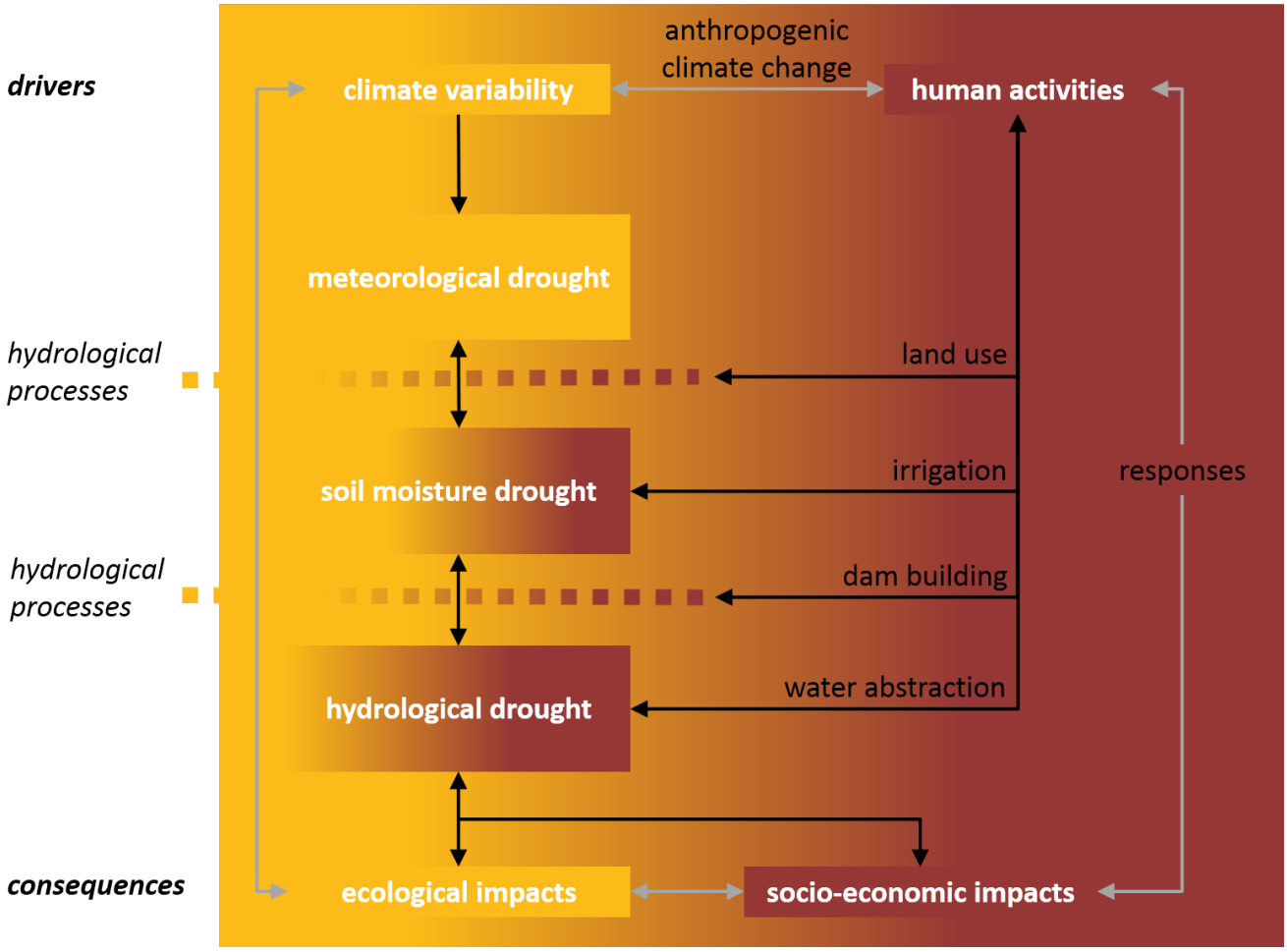
In the current human-modified world, or 'Anthropocene', the state of water stores (soil water, groundwater) and fluxes (river flow) has become dependent on human actions as well as on natural processes. Hydrological droughts are the result of a complex interaction between meteorological anomalies, land surface processes, and human inflows, outflows and storage changes. Our current inability to adequately analyse and manage drought in many places points to gaps in our understanding of this interaction and to inadequate data and tools to study it in depth. The Anthropocene requires a new framework for drought concepts, definitions and research. To progress the field, the drought conceptual framework needs to be revisited to explicitly include human processes driving and modifying hydrological drought development. Here we will give recommendations for more robust drought definitions in the Anthropocene, distinguishing between climate-induced, human-induced and human-modified hydrological drought. Additionally, our understanding and analysis of drought need to move from single driver (i.e. meteorological anomalies) to multiple drivers (i.e. meteorological anomalies and anthropogenic water abstraction) and from uni-directional (i.e. propagation from driver to drought to impacts on society) to multi-directional (i.e. feedback responses from society that affect drought). Based on literature reviews, our own previous work and current studies done through the Panta Rhei network, we visit example catchments around the world where human and natural drought processes are strongly interrelated. We discuss drought development in relation to natural and human drivers, responses to drought, both positive (i.e. more abstraction aggravating drought) and negative (i.e. water management alleviating drought) feedbacks, with the aim to get a more general understanding about drought in the Anthropocene. Based on the case studies, we identify research gaps and propose analysis approaches for drought in the Anthropocene, requiring qualitative and quantitative data as well as mixed modelling approaches on different scales. We expect this will shape the drought research agenda for the coming years, or even decade.

This work has been developed in the framework of the IAHS Panta Rhei working group "Drought in the Anthropocene".

Keywords: drought, Anthropocene, conceptual framework



Optimal investment and location decisions of a firm in a flood risk area using Impulse Control Theory

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Flooding events can affect businesses close to rivers, lakes or coasts. This paper provides a partial equilibrium model which helps to understand the optimal location choice for a firm in flood risk areas and its investment strategies. How often, when and how much are firms willing to invest in flood risk protection measures? We apply Impulse Control Theory and develop a continuation algorithm to solve the model numerically.
We find that, the higher the flood risk and the more the firm values the future, i.e. the more sustainable the firm plans, the more the firm will invest in flood defense. Investments in productive capital follow a similar path. Hence, planning in a sustainable way leads to economic growth. Sociohydrological feedbacks are crucial for the location choice of the firm, whereas different economic settings have an impact on investment strategies. If flood defense is already present, e.g. built up by the government, firms move closer to the water and invest less in flood defense, which allows firms to accrue higher expected profits. Firms with a large initial productive capital surprisingly try not to keep their market advantage, but rather reduce flood risk by reducing exposed productive capital.

Keywords: optimal investment, location choice, flood, socio-hydrology, Impulse Control Theory, sustainability

Climate change risk assessment by Integrated Terrestrial Model: a bio-geophysical land surface model with human components

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Future climate changes possibly affect eco-system services, water resources, food production, energy supply, etc. It is important to understand the interaction between the changes in these complicated factors. In the present study, we develop an integrated terrestrial model which describes the natural biogeophysical environment as well as human activities. In the integrated model, a global vegetation model VISIT (Ito et al. 2012), water resource model H08 (Hanasaki et al. 2008, Pokhrel et al. 2012), crop growth model PRYSBI2 (Sakurai et al. 2015), and land use model TeLMO (Kinoshita et al., in preparation) are coupled to a land surface model MATSIRO (Takata et al. 2003, Nitta et al. 2014), which is a component of global climate model MIROC (Watanabe et al. 2010). Output variables of each sub-model are passed to other sub-models during the time integration. The time intervals of variable exchange are from hourly to monthly or yearly. For example, the crop yields [ton/ha] calculated by PRYSBI2 is used in TEMO which calculate the land use change (crop or natural vegetation area) of next year. The projected land-use map is used in all other sub-models. The water resource model H08 considers the irrigation process (water withdrawal from rivers) as well as dam operations in large rivers, which affects the state of the soil moisture and the river flows in the land surface model. We will present the state of the model development, and results from the historical and future simulation. In the historical simulation, we validated the model output such as river flow, irrigated water, crop yield, and ecosystem productions by comparing to the observed or reanalysis data. Based on the future simulation, we also assessed the risk of future climate change by investigating the relationship of possible cropland area expansion and crop productions and so on.

Keywords: Climate change, Water resources, Land use

Allocating environmental water and impact on basin unemployment: Role of a diversified economy

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Water diversion for environmental purposes threatens many agricultural communities. This paper focuses on the water-agriculture-environment nexus in the Murrumbidgee River Basin, Australia, and attempts to explain how reduced water allocation to agriculture aimed at protecting the environment in turn impacted the wider economy and the community. Predictably reduced water allocation saw declines in agriculture production and employment. Despite this, paradoxically, the basin unemployment rate declined and basin median household income increased. To understand and interpret this, we first analyze available labour, economic and hydrology data, and then develop a simple dynamic model to interpret the observed pattern of basin employment and unemployment. Data analysis revealed the likely causes behind the paradox as (a) out-migration of people from the basin, and (b) absorption of the labour force in the fast growing non-agricultural sectors of the diversified basin economy. The model simulations reinforced this interpretation. Further model simulations under alternative realities of out-migration and sectoral transformation indicated that basins embedded in faster growing national economies, and are more diversified to begin with, are likely to be more conducive to agriculture sector reform (e.g., reduced water allocation) and environmental regeneration. This is a sobering message for other regions experiencing environmental degradation due to extensive agricultural development.

Keywords: socio-hydrology, employment, water management, water-food-environment nexus, sectoral transformation

Towards a Earth System based Understanding of Social Ecological Landscapes in the Anthropocene

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This paper analyzes the conceptually challenging endeavor of integrating an earth science based perspective with social ecological landscapes. Social ecological systems (SES) emerged as a key idea in ecology in the 1980s, with concepts such as ‘ecological resilience’ (Holling 1973) and ‘emergence’ (or nonlinear, non-equilibrium dynamics) (Holling, 1986, 1996) initially coming under focus. Over the years, sophistication of SES models progressed, leading to understanding of episodic buildup-conservation-release-reorganization of energy in the landscape (also referred to as ‘panarchy’ or ‘adaptive cycle theory’; described in Gunderson and Holling 2002), and the crucial role of ‘ecological memory’ or ‘path-dependence’ in unfolding of landscape-level processes (Stuart Chapin III et al. 2009). Those insights have obvious implications for management of complex systems that defy linear modeling and stability based solutions. Specifically referring to watersheds, Holling et al (1995) observed that short-sighted engineering based approaches can erode the resilience of complex systems by interfering with hydrological and ecosystemic components and their mutual interaction pathways. However even as considerable attention was given to the integration of ecological and human components and calls were made to study them from ‘cross-scale frameworks', relatively little attention was given to land-formation and erosional processes operating over geological time (deep time). With the emergence of the Anthropocene concept (Davies 2016), it has now become imperative that we extend our understanding of complex adaptive social ecological landscapes to appreciate how land-formation evolved over deep time, and how and to what extent human agency (anthropos) is an endogenous component of such processes (in geological time and geomorphic scale). This paper reflects on the continuum of mountain uplift and denudation, flow and deposition dynamics of river systems, and episodic transformation events to argue that this new understanding of landscapes must incorporate humans to posit them in a geological ‘context’. This requires at once a descriptive and reflexive (based on the critical deconstruction of the concept) understanding of the Anthropocene; one that allows us to understand the true scale of the human ‘blip’ on the evolving landscape.

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Keywords: Social Ecological Landscape, Complex system, River system dynamics, Earth system perspective, Anthropocene

Modeling and Optimization of Low Impact Development Layout Designs for Urban Flood Management

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This study develops a novel systematic optimization model for urban flood management by combining multiple Low Impact Development (LID) devices, taking into consideration a Benefit-Cost (B/C) Analysis. The contributions provided by this study include: (1) analysis of flooding consequences on the development of a megacity; (2) development of an innovative technical approach enabling an automatic and effective optimization process, linking with newly considered interdisciplinary embedded simulation model; and (3) proposal of adaptive solutions using a combined layout design scheme, by considering the economic hydrology-statistic aspect. Our investigation sets the Benefit/Cost ratio as the objective function in order to deal with flooding in all return periods (RPs). The decision variables correspond to the allocated areas and quantity of LID devices, including porous pavements, bioretention cells, infiltration trenches, rain barrels, vegetable swales, green roofs, and tree boxes. Under such layout, the flooding loss was simulated with a Storm Water Management Model (SWMM), and the optimal solution was solved by employing a Simulated Annealing (SA) algorithm. Min-Sheng Community in Taiwan is chosen as study area for demonstrating the applicability of the developed model. Results show that the B/C ratio of identified optimal design can reach 1.448, with green roofs and bioretention cells as main devices, and rain barrels and porous pavements as secondary supplies. Regarding rainfalls in all return periods, the peak flows and delay of peak times downstream of Fu-Yuan Pumping Station can decrease significantly in the range of 5.75-29.80% and 12.50-20%, respectively; and 9.52%-23.49% and 12.50%-37.5% at the subcatchments. The efficiency of flood detention is higher for low RPs than high RPs, while the time-delay ability is smaller.

Keywords: Flood mitigation and adaption, Low Impact Development, optimal layout design, Storm Water Management Model, Simulated Annealing, sustainable water management

Incorporation of a seawater desalination scheme into a global hydrological model

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Seawater desalination is a technology for providing fresh water to coastal arid regions. A model was developed to estimate the areas where seawater desalination is likely to be used as a major water source and the likely volume of production. The model was applied to the year of 2005 and showed fairly good reproduction of the historical geographical distribution and national production of desalinated water in the world. The model was applied globally to two periods in the future (2011-2040 and 2041-2070) under three distinct socioeconomic conditions, i.e., SSP1, SSP2, and SSP3. The results indicate that the usage of seawater desalination will have expanded in geographical extent, and that production will have increased by 1.4-2.1-fold in 2011-2040 compared to the present (from 2.8x10^9 m3 yr-1 in 2005 to 4.0-6.0x10^9 m3 yr-1), and 6.7-17.3-fold in 2041-2070 (from 18.7 to 48.6x10^9 m3 yr-1). The estimated global costs for production for each period are USD 1.1 10.6x10^9 (0.002-0.019 % of the total global GDP), USD 1.6-22.8x10^9 (0.001-0.020 %), and USD 7.5-183.9x10^9 (0.002-0.100 %), respectively. The large spreads in these projections are primarily attributable to variations within the socioeconomic scenarios and technological assumptions.

Keywords: water resources, adaptation

Exploiting the current flood of global datasets: How do humans impact and respond to hydrological extremes?

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Hydrological studies have widely investigated human impacts on drought and flood events, while conversely social studies have explored human responses to hydrological extremes. However, the phenomena emerging from their interplay, i.e. both impacts and responses, are still poorly understood. Thus, state-of-the-art methods fail in assessing future change in hydrological risk and, as a result, while risk reduction strategies built on these methods can work in the shorter term (2-5 years), they often lead to unintended consequences in the longer term (20-30 years). In this context, this paper discusses the opportunities offered by the current proliferation of worldwide archives and datasets for uncovering dominant patterns of human impacts on, and responses to, drought and flood events. They include global hydrological models, worldwide databases of losses and fatalities, satellite data as proxies of economic activity and population distribution, global land-use maps, datasets of irrigation, information about flood protection standards in different countries as well as worldwide archives of dams and reservoirs. Initial efforts to exploit this ongoing flood of global data and unravel the way in which societies shape, while being shaped, hydrological extremes are reviewed. Then, the paper discusses the potential of these global studies in advancing our understanding of where, how and why hydrological risk changes over time, thereby supporting the development of policies and strategies to reduce the negative impacts of droughts and floods, such as fatalities and economic losses, while maintaining the ecological benefits of hydrological variability.

Keywords: socio-hydrology, drought, flood risk, human-water systems

The essentialism of the Flood Plain analysis and flood monstrosity subject to loss in the catchment of Yamuna River through hydrodynamic modeling

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The anthropogenic activities inside and in the proximity of the floodplain diminish the river margins and the consequence of which is the increased flows in the river. The encroachment of riverbed promotes waterlogging and flooding in urban areas, thus causing loss of property, human life etc. This necessitates a comprehensive study of the flood plain and changes taking place in its proximity in order to carry out any further activities with certainty. In this study, the simulations are carried out using two-dimensional model in the Yamuna River with focus on the Delhi region, India. Present study demonstrates the hydrodynamic calibration and validation of iRIC (International River Interface Cooperative) model, to reproduce the flow in the Yamuna River for different return period. The iRIC model was employed effectively for the expanse of 47 km flood plain of the Yamuna River in the Delhi region from Palla in the upstream to Jaitpur in the downstream. Simulated flood flows were used to evaluate floods of once in 10, 20, 25 and 30 years return periods using standard flood frequency analysis methods on the rainfall data for the extent of 1951 to 2013. The simulation result obtained from the model were compared and validated with the stage values at various gauge locations existing inside the realm of interest. Stage discharge relationship is set up by adopting the optimum value for Manning’ s roughness coefficient at various gauge stations. The model validation results indicated that the model was able to mimic the flood depth in Yamuna River. The understanding of the extent of the flood and the areas affected is gained by assessing the simulations. Simulation results revealed that the encroachment of flood plain have increased the severity of the floods, and any further encroachment of the flood plain needs to properly examined and weighed before being implemented. The model also offers a potential platform for future evaluation of any other alternatives considered either to further encroach or restore the Yamuna floodplains.

Keywords: Flood, iRIC (International River Interface Cooperative), Yamuna River, Hydrodynamic Model, Water level

Modeling and prediction of pollutant load outflow from the Yangtze River Basin

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Along with the increase in industrial and domestic wastewater and use of chemical fertilizers due to rapid economic development, the pollutant load of the Yangtze River basin gradually increases from upstream to downstream, and simultaneously, the amount of the pollutant load transporting to the sea has been increasing annually. This research aims to model the pollutant load outflow from the Yangtze River basin. For that purpose, we have developed an evaluation model for the circulation of water and materials in the river basin by incorporating the mass balance model in the SWAT (Soil and Water Assessment Tool) model (Arnold et al., 1998). The model allowed us to predict the influences of land use, river basin renovation activities, and management projects on the circulation of water and materials in the catchment basin, taking into account various soils, land use practices, and land management systems. A geographic information systems (GIS) database consisting of landforms, land uses, soil types, and soil characteristics was required for data input into the assessment model. Climate dataset consisted of daily maximum, minimum, and average temperatures, humidity, rainfall, wind velocity, and the amount of solar radiation. For validation of the model, we used observation data for water quality from 2004 to 2010 collected at the major hydrological stations along the main stream of the Yangtze River, including Pingshan, Zhutuo, Yichang, Shashi, Hukou, and Datong hydrological station about 550 km from the estuary.
The model was calibrated by the observation data during 2004-2006 and validated by the data during 2008-2010. The validation showed that the monthly flow variations were modeled accurately, although the correlations were lower for the downstream area than for the upstream area, and the modeling ability for phosphorous load was lower than that for nitrogen load. We used the validated model to estimate the distribution dynamics of the pollutant load of both nitrogen and phosphorus outflow, such as the total nitrogen (T-N), nitrate nitrogen (NO3-N), nitrite nitrogen (NO2-N), ammonium nitrogen (NH3-N), total phosphorous (T-P) and dissolved phosphorus (DIP) from the the Yangtze River. The simulation results showed that in the decade from 2001 to 2010, the amount of NO_3-N increased by 2.9 times, NO_2-N increased 3.2 times, and NH_3 N increased 3 times compared to values from the 1980s (Duan et al., 2000). In order to verify these estimated results further, we also measured the water quality at the Datong hydrological station from 2011 to 2014 (Table 1), and found that the average annual amount of transported NO_3-N, NO_2-N, and NH_3-N still keep on the high level condition, and increased by 2.2 times, 3.2 times, and 3.5 times respectively compared to values from the 1980s (Duan et al., 2000). Therefore, we conclude that the pollutant load outflow had remained at a high level during 2000-2014.

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Keywords: Pollutant load, Nitrogen, Phosphorus, Yangtze river basin

Table 1: Average annual concentration (mg/L) and total outflow (10^4 t) of total nitrogen (T-N), total phosphorous (T-P), nitrate nitrogen (NO_3-N), nitrite nitrogen (NO_2-N), ammonium nitrogen (NH_3-N), and dissolved phosphorus (DIP) observed at the Datong hydrological station,

	T-N	**T-P**	**NO_2-N**	**NO_3-N**	**NH_3-N**	**DIP**
	Average annual concentration (mg/L)					
2011	2.43	0.15	0.04	1.71	0.45	0.11
2012	2.35	0.13	0.03	1.62	0.49	0.09
2013	2.47	0.15	0.02	1.65	0.61	0.11
2014	2.70	0.13	0.04	1.85	0.46	0.11
Average	2.49	0.14	0.03	1.71	0.50	0.11
	Annual total outflow(10^4 t)					
2011	162.17	9.81	2.42	114.05	30.20	7.64
2012	235.01	12.57	2.92	162.08	49.19	8.79
2013	194.88	11.45	1.55	130.19	48.13	9.00
2014	238.70	11.60	3.10	163.50	40.90	9.50
Average	207.69	11.36	2.50	142.45	42.11	8.73

Comprehensive Benefit Evaluation of Typical Regional Large Scale Reclamation in Chin

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The coastal area makes great contributions to human survival and social development. In recent years, a new round of development pattern has formed in coastal regions in China due to the approval and implementation of several national coastal development strategies. Sea reclamation played a key role in the sea use of national important projects construction and the development of the eastern coastal zones in China. The regional large-scale reclamation planning system had been implemented by SOA since 2006 in order to promote intensive and economical utilization of marine resources. By the end of 2014, 104 regional large-scale reclamation plans had been approved with more than totally 1100 km^2 reclamation area [1]. However, there was a huge impact on marine ecological system and the sustainable development of regional society and economy brought by large-scale reclamation. There were three typical regional large-scale reclamation plans implemented in Hebei Province in Bohai Sea regions, such as the Bohai new development zone, Caofeidian industrial zone and Jingtang harbor zone, whose total reclamation area and regional large-scale reclamation plan quantity ranked first in China. So that above three regional large-scale reclamation zones were taken for examples and their actual comprehensive influences were evaluated including marine environment, society, economy and implementation schedule impacts. The results showed that the economic benefits were remarkable, but the negative effects of sea reclamation could not be ignored. Especially the problem of idle land was very serious. Moreover, the regional marine environment quality was still unoptimistic, and the shallow tidal constituent structure was slightly changed due to dramatic coastline changes by large-scale reclamation.

Keywords: regional large-scale reclamation plan, marine environment, society and economy

Assessment of Climate Change Impact on Cooling Water: Economic Evaluations for the Thermal Electricity Sector

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Due to global warming, it is concerned that cooling water for thermoelectric generation would be running short more frequently in many places of the world. We used a Computable General Equilibrium (CGE) model to quantify the socio-economic impact of a hypothetical shock of capital productivity, which represents shortage of cooling water on thermal power generation plants. The results showed that the magnitude of electricity generation change and subsequent economic indicators change due to 1% capital productivity reduction were varied by region. The mean electricity generation loss was largest in Southeast Asia and smallest in North Africa when an identical shock was given to all regions throughout the simulation period. Considerable regional differences in GDP and electricity price were attributed to not only the capital productivity, but also the amount of capital in thermoelectric sector and its contribution for GDP. Additionally, thermoelectric sector shock propagates into the global economy. These finding demonstrate the significance in quantifying the economic consequence of cooling water shortage.

Keywords: climate change, cooling water shortage, thermometric sector, socio-economic impact, computable general equilibrium (CGE) model

Levees grow: capturing a process of changing society with development of Levee Spatial Database in Kiso River basin, Japan

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In the era of the emergent Anthropocene, it is important to capture the feedbacks between physical and social processes [Savenije et al., 2014; Sivapalan, 2015]. Di Baldassarre et al. (2015) developed a framework to capture the feedback between floods and society based on a dichotomy of “green society” which cope with flooding by resettling out of flood-prone area or “technological society” which is deal with flooding by building levees.

Modern Japan can be categorized as a technological society that started from the Meiji era (1868-1912). Modern hydrological technologies were imported from Dutch engineers and modern flood prevention projects were also started. Before the Meiji era, discontinuous levee systems known as "*Kasumi*" or "*Wajyu* "(ring levee) were the major flood prevention structures, which protected communities from frequent floods. These traditional levees enabled the communities to live in harmony with floods. However, the traditional levee systems were gradually replaced by modern continuous levees starting from the Meiji era, with constant increase in length until the present era. It is important to capture the historical process of Japan’s evolution into a technological society through the process of levee growth.

This study aims to capture the processes of levee growth by developing a "Levee Spatial Database" in Kiso River basin: this system consist of position information of levees in several eras which are manually entered into GIS from a series of historical topographical maps from Meiji era to present. The result shows the processes of levee growth and shrinkage with changing land use and increasing population in the flood-prone area. We will discuss the phenomena and mechanisms of levee growth/shrinkage in the view of feedbacks between physical and social processes of changing society in Japan.

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Keywords: socio-hydrology, levee growth, technological society

Including irrigation in flood inundation modelling –An initial exploration of the Mekong Delta

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Deltas are home to approximately 7% of global population and play a crucial role in regional food security owing to the favorable conditions for agriculture. As a result, these areas are often heavily irrigated as humans strive to use the local water resource to maximise production. This study aims to incorporate irrigation practices into the LISFLOOD-FP hydrodynamic model to determine the impact of irrigation on the flood dynamics of the Mekong Delta, one of the most intensively irrigated deltas. Irrigation data is based on global databases of irrigation area, crop type and crop calendars, supplemented with local information allowing for this approach to be used across irrigated areas around the world. This study therefore builds upon the localized estimates of flood storage capacity of paddy fields through the region and generates a new estimate across a wider area that is subsequently used to assess the impact on the hydrodynamics and flood inundation pattern. It is envisaged this approach can be used for future analysis of the impact of the changing irrigation practices of the Mekong Delta.

Keywords: Flood, Irrigation, Mekong Delta

Human in the Loop of Managing Early Warning of Coupled Dynamics and Risks with Poor Observations, Incomplete Understanding and Hybrid Modeling

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Here we address coupled human-water dynamics, especially with poor observation networks and incomplete understanding, by using emerging hybrid models. Human-in-the-loop (HITL) is defined as a model approach that requires human interaction. In HITL simulation, humans are usually a component, thereby influencing water-systems outcomes, sometimes in such a way difficult to reproduce exactly. From a Brazilian case study, we combine (1) a former application of a qualitative analysis of the early warning process in disaster management (see Horita et al, 2016) with (2) a novel, plausible HITL approach, viable for issuing anticipatory alerts on flood risks at a national scale. There are more than 40,000 flood-and-landslide prone areas officially mapped in Brazil. Also, 1 in 5 Brazilian municipalities depicted strong water-risks to population from hydrometeorological processes. Official alerts issued from CEMADEN-MCTIC are delivered at the municipality scale (community focused), with high uncertainty at the catchment scale (system driven). For that reason, a new generation of HITL depicts reasonable conditions for early warning of coupling dynamics and moving scales under complex realities of growing urbanization. In this contribution, we propose a new HITL in comparison with the observation network and alert database of the National Center of Monitoring and Alerts of Natural Disasters (CEMADEN/MCTIC), with more than 3,000 real time sensors, integrated at a 10-min time scale, installed in ca. 1000 municipalities. Novel indicators from this new HITL approach, based upon surrogate variables of hazard, vulnerability and exposure of flood-prone communities of Brazilian states, are here depicted. With emphasis in the North-East Region and South-East region, we derive HITL relations to help CEMADEN-MCTIC crisis room and the decision-making process of alerts at the national scale. Because the great nature of uncertainty, complexity of factors and cascade of decision-making rules, HITL should invoke promissory pathways for hybrid modeling under incomplete understanding of coupled human-water dynamics across scales significant to stakeholders. Reference and Supplementary Material: Horita, F., de Albuquerque, J., Marchezini, V., Mendiondo (2016) A qualitative analysis of the early warning process in disaster management, Short Paper, In: Community Engagement and Practitioner Studies Session, ISCRAM 2016 Conference (proceedings), Rio de Janeiro, 2016 (http://www.agora.icmc.usp.br/site/wp-content/uploads/2016/03/horita-iscram2016.pdf)

