# 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.

Works referred:

Davies, J.D. (2016). *The Birth of the Anthropocene.* UC Berkeley Press.
Gunderson, L.H. and Holling, C.S. (2002). *Panarchy: Understanding Transformations in Human and Natural Systems.* Island Press.
Holling, C.S. (1973). Resilience and Stability of Ecological Systems. *Annula Review of Ecology and Systematics 4.* pp 1-23.
Holling, C.S. (1986). The Resilience of Terrestrial Ecosystems: Loca Surprise and Global Change. In Clark, W.C. and Munn, R.E. (Eds). *Sustainable Development of the Biosphere.* Cambridge University Press. pp 292-320.
Holling, C.S. (1996). Engineering Resilience versus Ecological Resilience. In Schulze, P.C. (Ed). *Engineering within Ecological Constraints.* NAP. pp 31-44.
Holling, C.S. Schindler, D.W., Walker, B. and Roughgarden, J. (1995). Biodiversity in the Functioning of Ecosystems: An Ecological Primer and Synthesis. In Perrings, C. Maler, K,G., Folke, C. Holling, C.S. and Janson, B.O. (Eds). *Biodiversity Loss: Ecological and Economic Issues.* Cambridge University Press.
Stuart Chapin III, F, Kofinas, G.P and Folke, C (Eds) (2009). *Principles of Ecosystem Stewardship.* Springer.

 

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.

- References:
Di Baldassarre, G., A. Viglione, G. Carr, L. Kuil, K. Yan, L. Brandimarte, and G. Bloschl (2015), Debates—Perspectives on socio-hydrology: Capturing feedbacks between physical and social processes, Water Resour. Res., 51, 4770–4781.
Savenije, H. H. G., A. Y. Hoekstra, and P. van der Zaag (2014), Evolving water science in the Anthropocene, Hydrol. Earth Syst. Sci., 18, 319-332.
Sivapalan, M. (2015), Debates-Perspectives on Socio-hydrology: Hydrologic change and the “tyranny of small problems” –Socio-hydrology, Water Resour. Res., 51, 4795–4805.

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 )

 