



## Energy, water and climate nexus: A case study of Cameroon

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**Nexus 2014: Water, Food, Climate and Energy  
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**Abstract Book**

**Energy, water and climate nexus: A case study of Cameroon**

Emmanuel Ackom, UNEP Risoe Centre

Cameroon is a country that is well endowed with natural resources including fertile arable lands, freshwater bodies, crude oil and other energy sources. The country's oil exploitation however results in significant pollution of Cameroon's land, water and air. Modern bioenergy is seen as having good potential to offset the reliance on crude oil. This study investigated the biomass resource availability from agricultural residues for liquid biofuel (as transportation fuel) and bioelectricity. Our findings indicate that sustainably extracted agricultural residues could yield 1.11 million bone dry tons per year. Using current bioconversion efficiency rates, the residues could potentially yield 0.12-0.32 billion liters of ethanol annually that is enough to offset 18-48% of the national consumption of gasoline. For bioelectricity generation, the same residues could provide 0.76-2.02 TW h, or 15-38% of Cameroon's current electricity consumption. The potential water savings and avoided greenhouse gas emissions from the use of agricultural residues for liquid biofuels and bioelectricity relative to crude oil have also been estimated. Modern bioenergy from agricultural residues does not pose concern to food security in Cameroon but rather it could be effectively utilized to improve food availability through provision of energy for increased production and preservation. Additionally, reduced water utilization and greenhouse emissions relative to crude oil are positive advantages associated with the use of agricultural residues. The study provides policy recommendations to help encourage modern bioenergy applications from residues in Cameroon.

**Leveraging the water-energy-food nexus for a sustainability transition: Institutional and policy design choices in semi-arid India**

Rimjhim Aggarwal, Arizona State University

Given the critical - but often subtle - feedbacks between water, energy, and food security, a nexus approach that integrates management and governance across sectors and scales is increasingly being advocated in research and policy circles. As a first step, such an approach calls for an integrated multi-disciplinary assessment of the externalities across sectors and tradeoffs involved in enhancing security in one sector on the other sectors. Recent research efforts have focused on understanding these tradeoffs, say, through estimating the energy costs of expanding irrigation for greater food security; or estimating the embodied land and water costs in increased energy production. While such efforts have increased awareness about the inter-connectedness of such issues, the fundamental question of how such an understanding influences decision-making and how it can lead to coordinated action towards a transition to more sustainable pathways still remains largely unanswered. The long legacy of sectoral organization of political and bureaucratic structures has led to a fragmentary policy and

institutional landscape, on which cross-sectoral public action and coordination poses several challenges. Moreover, poorly defined property rights, imperfect or absent markets, and uncertainty about resource dynamics imply that economic signals about relative scarcity in one sector are not necessarily clear to decision makers in the other sectors. In this study, we examine these issues related to water-energy food nexus in the context of semi-arid groundwater irrigated regions of western and southern India. Using a social-ecological systems framework, we begin by characterizing some of the key inter-dependencies among food, water, and energy at the farm household, village and state level. We then examine the factors that influence decision-making at these levels, and the extent to which these decisions internalize the externalities. Specifically, we examine the role of energy pricing and rationing policy on groundwater withdrawals and type of crops grown. Finally, we examine several emerging examples of innovative policies and institutions that have leveraged the synergies among sectors. Although these examples do not necessarily provide optimal solutions, these provide some clues as to how decision-making within individual sectors can be influenced through institutional and policy design to transition towards more sustainable pathways in a second best world. We conclude by exploring what lessons these cases might hold for navigating these tradeoffs in other contexts.

**Artisanal fisheries in the nexus: a study on traditional fish processing methods and sustainable development**

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Purpose- The small scale fishers in coastal or inland communities are vulnerable to plethora of socio-ecological variables in spite of their importance in the food security equation. Fish processing mostly smoking and less commonly sun-drying, are traditional methods of fish preservation in sub Saharan Africa. The mangroves provide the source of wood energy. This clearly is unsustainable with the consequent threat on the regulatory services of the mangrove when violent storms are increasingly being experienced. The nexus approach required that objectives of climate mitigation measures and secured local livelihood must be met to ensure the non-negotiable right of human to water and food. The objective of our study is to present local scenario which seeks to contribute to understanding of peculiarities of the artisanal fishers globally in the green economy approach. Design/Methodology- Open and closed questionnaires were administered to fish smoking operators within coastal fishing communities in Lagos State of Nigeria to generate data on type of kiln, types and sources of wood, fish production capacity, amount of wood used and access to financial capital. Proximate composition was thereafter conducted on the most frequently used wood in the community to generate data on total biomass energy. The carbon footprint and other greenhouse gases arising from fish smoking were estimated. Findings-It was found that over 98% of the smokers depended on the woods from the mangrove. The commonly used materials were *Gossweilerodendron balsamiferum*, *Khaya ivorensis* and *Cocos nucifera*. A total of 5.6-10.2kg of woods were used to produce total biomass energy ranging from

97,096+855 - 767,880+25,404 to MJ/wk required to preserve 45.5+1.50-98.7+3.51 Kg/wk of prawns, shrimp, catfish and tilapia with an estimated CO<sub>2</sub> of 9,139.1+28.28- 72,028+2,382.98 tons/wk. The *Cocos nucifera* was the most fuel efficient and produced the list amount of GHGs gases. The mongers would consider alternative solar technology when appropriate mechanism that enable this transition is in place. Practical Implication-Fish processing though an integral process of guaranteeing food security may unwittingly be both the driver and victim of the loss of mangrove, biodiversity, air pollution and increased carbon output. Although, biomass energy is regarded as carbon neutral our study draws out the need for a more detailed study that will quantify the interactions and feedbacks between the water, energy and food in both space and time scale arising from livelihood heavily dependent on biomass energy. Originality and Value Information provided in this study is significant as it underscores the connectedness of artisanal fisheries in the water, energy and food security nexus. It shows system efficiency of an integral part of artisanal fisheries is low as destruction on ecosystem may in the long run out weigh the benefit of food security.

**Understanding water as fountain of socio-spatial inequality in Nigeria: the interplay of culture, economics and institutions**

Emmanuel Akpabio, University of Uyo

What is water and how is it used in the construction and representation of the social fabric of the society? This question has been raised at different theoretical perspectives without adequate understanding on their specific empirical manifestations. For instance, there seems to be a general consensus mostly among social scientists that water is not only a material substance (H<sub>2</sub>O), it reflects many social meanings and values deeply interwoven with contextual experiences. Discussing water from the social perspective can reveal the realities of social relations and differentiations, symbolic values and the exercise of power and control in a given society. This paper explores social meanings, spatial and institutional practices associated with water and their significance in the construction of social and spatial inequalities in Nigeria. Drawing on specific meanings and beliefs across some ethnic areas, the paper has highlighted some aspects of social and symbolic powers of water and water places in defining and segregating individuals and groups. In a specific case illustration, access to water has been used to mirror how social and spatial inequalities are reproduced through the mechanisms of cultural, institutional, material and socio-economic practices. While water has served to foster cultural discrimination especially in the preservation of patriarchal gender and power relations mostly in rural communities, its production and reproduction have emerged at the center of capital accumulation and dispossession through some forms of material, economic and institutional practices at urban scale. Rather than serve the interest of the low income class, the paper argues that these practices propagate and deepen social inequality, economic marginalization and coping problems.

## **Disentangling the water, food and energy nexus in agriculture: A policy option for India**

Upali Amarasinghe, International Water Management Institute

In India, the nexus between water, food and energy has reached a tipping point. The country can no longer underestimate the crises or delay addressing the issues emanating from the nexus, which already constrain sustainable economic growth in many regions. This paper assesses the trends and turning points of groundwater irrigation, agricultural production and energy consumption in the state of Andhra Pradesh (AP), India, which exemplifies the dire situation that prevails elsewhere in the country. It also shows that the state can reduce agricultural electricity consumption and still achieve a Pareto optimal solution for all stakeholders: farmers, utility companies, the government and, most importantly, the environment. AP has an important place in economic, agricultural land- and water-scape in India. In 2011, the total population of India was 1.2 billion, of which AP accounted for 84 million people. Among the 32 major states in India, AP has the fifth largest population, fourth largest geographical area, second largest economy and 5 million hectares of net irrigated area (NIA), which is 9% of the total NIA of the country. The state has 23 administrative districts in three agro-climatic zones: Telangana, Rayalaseema and Coastal Andhra. Three distinct growth periods depict groundwater irrigation development during the last four decades. Dug wells, along with canals, were the main sources of irrigated area expansion in the 1970s and 1980s. A decline in the number of dug wells and the rapidly increasing number of tube wells were the main features of irrigation development trends in the 1990s. Post-2000 trends show a significant slowdown in the expansion of even the tube well irrigated area. Yet, groundwater depletion is an issue in many regions. Groundwater contributes to 69%, 67% and 23% of NIA in the Telangana, Rayalaseema and Coastal Andhra regions, respectively, and to 48% of the net sown area in AP. In some regions, the consumptive water use (CWU) (evapotranspiration) of crop production alone is a significant part of natural groundwater recharge. With depletion from other sectors, groundwater CWU in many locations are at or above the thresholds of natural groundwater recharge. Electricity consumption increased rapidly with groundwater use. The share of electric pumps in the state increased from 64% to 94% between 1991 and 2008. As a result, agricultural electricity consumption increased by 138% between 1991 and 2008, compared to a 57% growth in NIA using groundwater. Electricity supply is free to farmers, but a high cost has to be borne by the governments. Utility companies estimate the cost of agricultural electricity supply at a flat rate of about USD 0.08/kWh. The government transfers the estimated subsidy to the utility companies to mitigate their losses. The estimated farm power subsidy at the national level is more than USD 6 billion, which is more than the expenditure for health and education in some states. Econometric analyses of district-level data between 1999 and 2008 show that, every 1% growth in groundwater CWU has contributed to a 0.82% increase in agricultural electricity consumption and only a 0.12% gross value of crop output. Thus, a 1% reduction in agricultural electricity consumption will reduce 1.14% of groundwater CWU and will, in turn, reduce 0.14% of the gross value of output. At present, the marginal loss of gross value of output due to a reduction in electricity consumption is far less than the increase in subsidy for that amount of electricity consumed. In many districts, due to high production costs, marginal profits are much less than the subsidy that the

government has to payout. Thus, the direct transfer of the electricity subsidy to farmers for reducing electricity consumption is a financially attractive option, rather than the value generated in agricultural production at present. Such a solution can generate even higher environmental and socioeconomic benefits to all stakeholders. It will maintain, at least, the present level of benefits to farmers - the most important stakeholder in the nexus. Power utility companies can reduce losses by selling power to other sectors at a higher incremental rate. The state government can reduce the agricultural power subsidy. Domestic and industrial sectors can increase their productivity and output, for which inadequate power supply is a severe constraint at present. The environment will benefit by reduced groundwater depletion, which contributes to the drying of wetlands and streams, and water quality issues, at present. It is an incentive for farmers to increase efficiency of groundwater use and diversify cropping patterns to high-value low water-intensive crops. The utility companies will have to reduce losses in power transmission and distribution, which, at present, is conveniently included in the subsidy estimation

### **Optimizing Decisions and Policies: The Politics of Information, Water Scarcity, and Bioenergy**

Urooj Amjad, University of North Carolina at Chapel Hill

It is unclear whether decision makers have sufficient and appropriate information to analyze impacts of water scarcity and bioenergy production. The link between water supply services and bioenergy production is rarely made explicit, though commonly cited as a problem of balancing water scarcity and bioenergy production. In this study, the link between water scarcity for drinking water supply and bioenergy production will be examined, by analyzing processes of evidence based decision making within water utilities and evidence based policy within regulatory institutions in the United States and European Union, and to some extent Latin America and Africa. The political nature of information that transforms into evidence will also be examined, which informs the securitization of water for domestic use and bioenergy markets. Methods will include a combination of spatial analysis for links between drinking water sources and bioenergy production impacts on water quantity and quality, and content analysis of existing policy and regulation that influences water supply and bioenergy production. The relevance of the expected findings are lessons for optimizing water utility decision making, and policies that encourage bioenergy production, recommendations for enhanced evidence-based decision making and policy making generally, and a conceptual map of how drinking water supply is connected to bioenergy production that are socially, environmentally, and economically sustainable.

### **Food versus oil palm: how to solve this conflict?**

Eva Anggaraini, Humboldt Universitaet zu Berlin

Conflicts of interests related to food production and biofuel production have not been solved thus far. In some countries, food crops such as maize and soybean have been cultivated for biofuel production, and in other countries, in addition to forests, farming lands have been converted to bioenergy crop

plantations. The later contest between food production and biofuel productions is the focus of this paper. Smallholder is an important player in oil palm sector in Indonesia who contributes 40 percent of the total area of oil palm plantation. Such a big contribution is achieved at the expense of forest and arable land. Particularly, independent smallholders are mainly dealing with the conversion of arable lands into oil palm plantations in which competition between food crops and bioenergy crop (i.e. oil palm) becomes obvious. The study aims to identify policy and regulation related to food and bioenergy nexus and to analyze the coherence among them. Furthermore, the study attempts is to describe the complex situation of arable land conversion into oil palm production taking place at the local level based on case studies to get a reflection of the effectiveness of governance related to food and bioenergy nexus. The study uses primary data collected from the ground through interviews with farmers and local authorities, and secondary data from government reports. In Indonesia, food farming activities is mainly conducted by small-scale farms. The raising oil palm has made a big pressure for food farming as many farmers are tempted to grow oil palm in their limited farmland. The need for cash and the prevailing institutional arrangement of local market for oil palm fresh fruit bunches (FFB) are mentioned as major drivers of farmers' decision to grow oil palm (Anggraini & Grundmann, 2013). Converting farmland into oil palm has increased farmers' income liquidity which contributes to the changing consumption pattern of farmers' households. Significantly, it has created high dependency of farmers' households toward market in getting food. Villages in the studied region are almost filled by oil palm plantations. The delicate oil palm price due to international trade situation gives considerable risk for farmers as well as rural economy, as the economy is mainly determined by monoculture. Governance efforts are really lacking in this matter. At the national level government supports for the increasing food and oil palm production are equally great, but at the local level, the situation goes without control, thus arable land conversion for oil palm keeps taking place. Such a situation is indeed alarming for farmers, rural economy and national food security in general. Coherency in regulating food and biofuel sectors is required to improve the governance in food and oil palm production. Food and bioenergy nexus should go toward mutually reinforce rather than debilitate each other.

**Applying nexus thinking to investigate the water-energy-carbon implications of two low carbon futures for the City of Bristol, UK**

Rose Bailey, University of the West of England

Additional Authors: Enda Hayes; Christopher Scott; Chad Staddon; James Longhurst

This paper presents the results of current research applying Nexus thinking to two low carbon 2050 scenarios developed for the city of Bristol, UK. They are being used to frame a Delphi-inspired stakeholder dialogue on the energy-water-carbon nexus within the city, identifying synergies and trade-offs for managing securities within different low carbon transitions. This analysis and stakeholder process has applications for other growing urban centres globally. Cities are increasingly recognised as a key focus of activity for climate change commitments and environmental sustainability due to their



unique patterns of consumption, presenting both distinctive problems and opportunities in contemporary society. The concentrations of people and activities within a relatively small geographic area place considerable demands on resources beyond the boundary of the city, and directly and indirectly generates large quantities of polluting substances. This creates challenges for sustainable, secure provision of essential services and the meeting of environmental objectives. Climate change, both mitigation and adaptation, has arguably become a dominant discourse in environmental policy, research and practice. The all-encompassing nature of the problem results in unique environmental, social, technological, economic and political challenges for city development. It impacts all areas of society, requires cross-sector and -institution cooperation, and often exacerbates existing environmental pressures. Given increasing global urbanisation, how cities respond to the climate challenge will fundamentally shape global futures. The response to date by many cities has been a quantitative, focussed on the 'footprint', and usually shorter-term measures. This has limited use, particularly where significant transformation and multi-sector action is required. Participatory scenario methods, particularly those that utilise a normative approach such as backcasting, are useful for dealing with the temporal scale and multi-factorial nature of the climate change challenge. Through the creation of integrated, collaborative visions, different priorities and interests can be balanced, external factors considered, and a future that is broadly acceptable for all defined. These scenarios can be a powerful tool for engagement and stakeholder buy-in, as well as guiding policy and providing a framework around which other problems and decisions can be tested, such as the energy-water-carbon nexus. Nexus approaches can support a transition to sustainable futures beyond 'just carbon', by identifying and addressing externalities across sectors, building synergies, reducing trade-offs and generating additional benefits. By integrating nexus thinking on energy and water with existing scenarios research, low-carbon decisions can be tested against wider impacts to produce a more holistic and systemic future vision that maximises co-benefits, limits trade-offs and better meets environmental objectives. Furthermore, this integration helps to ensure that nexus thinking goes beyond supply and point of use ('pumps and turbines'), and is conceptualised in terms of wider decision-making. In the city of Bristol, UK, research using Delphi and backcasting methods with key stakeholders was undertaken to define possible low carbon scenarios for the city in 2050 (Bailey et al., 2012). This resulted in two narratives of the future, visualised through an interactive public engagement website: <http://www.futurebristol.co.uk>. These scenarios are now being used to frame discussions of the water-energy-carbon nexus in the city in an extension of the Delphi-backcasting process. Stakeholders are identifying synergies and trade-offs between availability, security, quality and cost of energy and water in the scenarios, mapping policy pathways and the implications of and to a low carbon agenda. The aim is to identify scenario features that offer the best solutions for the energy-water nexus, while being compatible with low carbon pathways. Using a scenario approach to frame the discussion also helps to move the nexus beyond operations and metrics to management and decision-making. The outcome is an improved understanding of the implications of low carbon transition pathways on resource management, how such management can be optimised within this framework, and also the contribution and impact that improved management can have on transitioning to a low carbon future. Using participatory scenario processes to frame the issue is a powerful way of ensuring decisions are 'future-proofed' as resilient

strategies across a range of scales, key stakeholders are engaged and involved, and a holistic approach is taken to management of resources.

**Impacts of climate change on cattle production and linkage with food insecurity in a pastoral region of East Africa**

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Climate change and variability can severely constrain the productivity of pastoral herds by reducing water availability, forage production and quality, and hence the carrying capacity of rangelands. To generate insights into how climate change and variability adversely affect cattle production and local livelihood in Borana pastoral system of Ethiopia, we analyzed long-term changes in cattle numbers and climate data of the study area. Climate data of the study area (covering 1970 to 2011) were obtained from the National Meteorology Agency of Ethiopia. Additionally, data on perceived changing trends in climate, rangeland condition as well as time-series cattle holdings collected from 242 households during the 2011/2012 field survey. A generalized additive model (GAM) and vector autoregressive model were fitted to assess the relationship among multivariate time series variables, particularly between cattle numbers and climate variables. The results showed that the area has characteristically bimodal rainfall with irregular onset and duration of both the long (CV=41.3%) and the short (CV=61.3%) rains. Spectral density analysis revealed a quasi-periodic pattern in the annual rainfall, with droughts recurring at approximately every 4.2 years in the region. The drought of 2010/2011 gave insights into how short-term climate variability can adversely affect livelihood bases and food security at local level. The annual precipitation was well above average from the mid 1970s to the early 1980s, but found to decline and remained below average thereafter. A downward trend in cattle population thus reflected a similar underlying scenario in the interannual rainfall variation. Accordingly, changes in cattle number were significantly associated with changes in rainfall while the effect of temperature was not significant. Similarly, precipitation, cattle numbers and their performances were also perceived to decline over time, having a consequent negative impact on milk production and food security. In conclusion, the study showed that climate change and variability were associated with declining cattle number, portending a precarious future to the sustainability of cattle production and household food security in the region.

**Resource Sufficiency Evaluation- A 21<sup>st</sup> Century Policy Perspective**

Ed Barry, Sustainable World Initiative

In designing a post-2015 global development agenda the UN Open Working Group (OWG) on the Sustainable Development Goals (SDGs) is seeking to formulate a workable set of global goals and targets that would be applicable to all nations, not just developing countries. In a "one-planet," resource-constrained world, universality is essential. For unless developed nations are able to reduce their claim on the world's resources, there may not be enough resources and ecological "space" to maintain economic progress in the developing world. Sustainable consumption and production must start with a clearer understanding of global resource limits and the metrics needed to determine what level of resource consumption is truly sustainable. This session will discuss resource sufficiency evaluation (RSE), an analytical and policy framework that allows countries to measure their bio-physical limits and what will be required to live within them. RSE is an essential complement to other efforts aimed at achieving sustainability. "Green economy" programs that improve the efficiency of human economic activity, are necessary, but not necessarily sufficient in today's resource-constrained world. While green technologies may help to de-link resource extraction from economic growth, they will not ensure progress toward global sustainability unless the aggregate level of resource consumption remains within sustainable limits. RSE helps countries determine what those limits are. This session will discuss why RSE is needed in today's world of increasing resource scarcity, how it operates holistically at the nexus of food, water, and energy, what bio-physical resource "balance-sheets" look like, how RSE will facilitate improved policy decision-making in support of future sustainable living, and the benefits that both developed and developing countries will realize if they incorporate RSE into their national planning.

**The Water Benefit Partners PPP- A Private Sector Mechanism for Financing Sustainable Water Projects with Water Benefit Certificates (WBCs)**

Jacob Bourgeois, First Climate Markets AG

To address growing global problems involving water scarcity and quality, new collaborations, technologies and business models are needed. Companies have become more aware of water-related risks in their own operations and supply chains, and those that ignore these threats face uncertain growth prospects and reputational risks. As a result, many firms are engaging in water-related initiatives beyond their own watersheds as part of a broader water stewardship strategy. In 2011, environmental asset management company First Climate set up Water Benefit Partners as a public-private partnership to investigate these issues. The PPP brought together the Swiss Agency for Development and Cooperation (SDC) with corporations including Nestl\_ and Bayer, technical advisers such as SGS and Markit and an advisory board composed of WWF Switzerland and the Gold Standard Foundation. The partners have developed a novel certificate-based initiative - the Water Benefit Certificate (WBC) mechanism - that addresses these concerns. The idea behind the WBC mechanism is to provide incentives for financing water projects around the world through the certification and sale of a project's

annually verified water benefits in the form of WBCs, borrowing lessons learned from the carbon offset market. These represent water saved, purified or supplied through a project activity that conforms to the Water Benefit Standard (WBS). Based on a market approach, the application and verification process under the standard will facilitate additional, beyond business-as-usual investments in water projects, especially in areas where water stress and water quality issues are particularly pressing and finance is urgently needed. The Gold Standard Foundation has been instrumental in developing the mechanism, and in mid-2013 it became the official administrator of the standard under its Gold Standard Water program. The certification cycle of WBC project activities largely mirrors that used by the Gold Standard Foundation to certify sustainable development carbon projects. Its experience in the carbon market and extensive network of NGOs and technical experts give it credibility and make it ideally placed as the WBC administrator. Securing financing for water projects through WBCs offers a number of advantages compared with official development assistance (ODA) and donor-based funding. These include long-term incentives to keep the project going, credibility derived from third-party verification and transparency as all projects have their details available online and are evaluated according to a common standard. Since its inception, the body of partners and collaborators has expanded significantly while being unveiled to the public. Recently, many new partners joined the PPP as corporate, technical and sounding board advisers including Carlsberg, Olam, World Vision, the International Federation of Red Cross and Red Crescent, the IUCN and Bonneville Environmental Foundation. In addition, an independent Water Technical Advisory Committee has been established at the Gold Standard Foundation responsible for approving and amending the standard as well as adopting new water project methodologies. This working standard will facilitate a number of diverse pilot projects starting in 2014 to demonstrate that the standard can deliver real, sustainable water benefits. Such projects will include WASH as well as water efficiency, purification and water-productive agriculture pilots.

### **Life cycle assessment of a residential scale aquaponic system**

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Additional Authors: Brian McCarthy; Suzanne Young; Jennifer Smith; Maya Trotz; Sarina Ergas

Introduction and Objectives: Our present food system fails to sufficiently support the nutritional needs of over 870 million people and continues to degrade the environment endangering future food production (FAO, 2012, Foresight, 2011). A critical component of this global food system is the practice of industrial agriculture. While industrial agriculture has produced greater crop yields, the negative environmental impacts and overuse of a water supplies raise concerns about continuing to grow food in this fashion (Lichtfouse et al. 2009). Problems with the present food system do not only occur on land; the ocean's resources are also in danger. Unsustainable fishing practices have caused the collapse of approximately one in four fisheries between 1950 and 2000 (Mullon et al. 2005). Despite these collapses, fisheries are a critical component of the global food system. Aquatic animals provide 15 to 20 percent of animal protein consumed (FAO, 2013) and in the next decade production from capture

fisheries and aquaculture combined will exceed the production of beef, pork, or poultry (FAO, 2012). Increased awareness of these problems and others facing our global food system is fueling the development of more sustainable food production technologies. Aquaponics, the combination of aquaculture and hydroponics, is an example of an alternative food production method. Fish and plants are produced simultaneously by reusing nutrients in fish production for the fertilization of vegetables. In theory aquaponic systems are an environmentally benign due to water and nutrient recycling but the environmental impact of these systems has not been empirically established. Life cycle assessment (LCA) is a tool used to assess the environmental impact of products or processes. It is a "cradle to grave" analysis, meaning that the assessment includes the raw material extraction through the final disposal of all components (EPA, 2006). The overall objective of this research was to explore the environmental impact of a residential scale aquaponic system using LCA. The LCA will be used to determine if the avoided use of fertilizer and pesticides help offset the environmental impact from electricity required for pumping and aeration. Materials and Methods: The LCA process is comprised of a four steps: goal and scope definition, inventory analysis, impact assessment, and interpretation as defined by International Organization for Standardization in the 14040 and 14044 standards. In the goal and scope definition the functional unit is determined (EPA, 2006). The functional unit provides a baseline for analysis and allows for direct comparison between systems. The functional unit used in this study was 1 kilocalorie (kcal) to account for the production of fish and vegetables (Phong et al. 2011). The system boundaries were from cradle to farm gate. Environmental impacts were quantified and aggregated into specific impact categories. The characterization step converts inventory data into equivalent units and allowing for the direct comparison of inventory results within impact categories (EPA, 2006). The following impact categories were used: global warming potential (GWP), eutrophication potential, acidification potential, abiotic resource use, energy use, and land use. A midpoint approach will be used due to the lower level of uncertainty (Goedkoop 2008). Inventory data was collected directly as the system was constructed at the University of South Florida. Databases available in SimaPro 7.0 were used to provide information on the background processes, emissions and resources used during production of the inventory materials. Specifically the Ecoinvent v 1.2, Franklin, IDEMAT 2001, and LCA food databases were used. The impact assessment was performed using SimaPro 7.0 (Pr\_ Consultants, The Netherlands). Preliminary Results and Discussion: A freshwater aquaponic system was constructed at the University of South Florida. The aquaponic system has a footprint of 5.6 m<sup>2</sup> and a total volume of 87 L. It is classified as a residential scale aquaponic system. The system has been operating with 25 blue tilapia since 09/13/2013. Approximately 36 basil plants have been supported hydroponically since 10/19/13. Inventory data was collected during the construction and a model is presently being developed in SimaPro 7.0.

### **Economy in Kenyan Deltas: Water, Renewable Energy and Climate Change Nexus Nature Based Conservation Model**

Kennedy Bwire. Institute of Environment and Water Management

Kenya's deltas are important natural resources providing enormous ecosystem goods and services. They hold and slowly release water for various uses, control flooding and pollution loadings, act as biodiversity hotspot and grazing grounds for livestock. However, their economic value have continued to be neglected and/or unrecognized by policy and decision-makers, especially their role in promoting sustainable development and achievement of Kenya's Vision 2030 - the country's development blue print. Consequently, they have been facing a myriad of challenges including encroachment for human settlement and urban development among others. Over the last decade, conflicts have been increasing in the major deltas in Kenya as the demands for competing land uses, natural resources utilization, nature conservation and demand for local deltaic community interests intensified. Attempts to reach rational decisions on wise use of the delta's resources for the present and future have largely failed due to divergent views and interests between different stakeholders. This has been exacerbated by key challenges that are facing the Delta's, interalia: destruction and loss of deltas habitats, poor land use practices, unplanned and unregulated human settlement, and unsustainable agricultural practices, declining water quality, ineffective strategies to address energy, water, livelihoods support systems and challenges of impacts of climate change in the deltas. In the face of pressing economic and environmental challenges, national and international efforts to promote green growth as a new source of growth have been intensifying. The recent United Nations Conference on Sustainable Development in Rio (RIO 20) underscored that the transition toward Green Growth and the building of a green economy is considered by a growing number of African and developing countries as a viable and necessary approach to development. Several African countries have taken the lead in defining their strategic approach to green growth and launching their road maps toward a green economy. Moving towards a green economy has the potential to achieve sustainable development and poverty eradication on a scale and at a speed not seen before. Green growth in deltas means enabling sustainable growth and creating prosperity by taking a holistic approach to sustainable management of deltas development--valuing human, social and natural capital, efficiently and sustainably producing goods and services and building resilience in a changing and increasingly interconnected environment. Adoption of green growth development pathway in deltas is necessary to preserve the livelihoods of deltaic communities through, for example, improved food security, universal access to clean energy, creation of green jobs, adoption of green technologies in order to maintain or restore environmental and ecological quality, reduced water stress in the face of climate change and competition for natural resources. This paper explores the potential of water, renewable energy and climate change nexus in the broader context of green economy as a driver of nature based conservation model in Kenya deltas. Using multipronged participatory approaches and tools, we provide strategic actions and recommendations toward achievement of green growth in the context of Kenya's deltaic ecosystems.

### **Confronting Energy, Food, and Climate Change Challenges: Analyzing Tradeoffs with ADAGE**

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Maintaining and improving future food and energy security poses key challenges globally, especially in the face of climate change. Global food and energy demand are expected to increase substantially in coming decades due to population and income growth. While agriculture and forestry can provide feedstocks for future energy production, the use of land to produce biomass for energy generation competes with demand for land resources to produce food, feed, and fiber. Simultaneously, agriculture is threatened under climate change, facing expected reductions in global productivity that will increase competition for land resources. The combination of these key factors influencing future supply and demand for agricultural commodities raises questions on optimal strategies for enhancing food and energy security while reducing GHG emissions. In this study, a computable general equilibrium (CGE) model -- the Applied Dynamic Analysis of the Global Economy (ADAGE) model, is used to examine how the global economy responds when facing these challenges. Though there are many studies analyzing these issues individually or combined to some extent, they are generally subject to limitations due to being static (for example, GTAP-BIO in Hertel et al. (2010)), characterizing the agricultural sector in a highly aggregated fashion (for example, the MIT Emission Prediction and Policy Analysis [EPPA] model (Reilly et al. (2012) has only one crop sector), or examining these cross-sectoral issues within a partial equilibrium model (for example, International Model for Policy Analysis of Agricultural Commodities and Trade [IMPACT]). The version of ADAGE used for this study is a recursive dynamic, multi-region and multi-sector CGE model. With greater sectoral/regional disaggregation than most CGE models, especially for the energy and agricultural/biofuels sectors, ADAGE has been widely applied for food, energy and climate change related studies, including evaluation of US Renewable Fuel Standards (Cai, et al, 2013; Birur et al, 2011) and assessment of climate change impacts on agricultural production (Beach and Cai, 2013). In this study, five scenarios are designed to explore questions regarding what should be done to mitigate climate change, while simultaneously enhancing energy and food security: 1) A business-as-usual scenario (BAU) where regional GDP projections are based on the reference case in the International Energy Outlook 2013; 2) A climate change scenario (CC) where crop and livestock productivity are affected by climate change with data drawn from an AGMIP study (Nelson et al 2013); 3) A biofuel policy (BIO) which uses the growth trend of renewable energy in the high oil price case in the International Energy Outlook 2013; 4) a climate mitigation policy scenario (CM) where a carbon tax is applied to all GHG emissions, including emissions from land-use change; and 5) A combined scenario (ALL) where CC, BIO and CM are implemented together. Our preliminary results indicate that despite continued increases in land productivity and energy efficiency in future decades, the effects of population and economic growth would dominate, leading to global increases in agricultural production, but also rising food and energy prices as well as continually growing GHG emissions in the BAU scenario. Comparing the climate change scenario with the BAU scenario, there are substantial reductions in global crop production and significant further increases in food prices, but little change in fossil fuel and biofuel production and energy prices, and only mild increases in CO<sub>2</sub> emissions due to land-use changes. Regions display different responses facing climate change. Relative to the BAU case, the implementation of a biofuel policy would lead to a shift in the mix of crops produced towards those used as biofuels feedstocks, raise food prices, and reduce oil consumption and price slightly. Meanwhile, GHG emissions are slightly reduced as a result of less oil consumption. In the carbon tax policy scenario, some cropland

is afforested to store carbon, leading to a moderate rise in food and energy prices and significant GHG emission reductions. When climate change, biofuel policy and a carbon tax are implemented together, we see even higher reductions in global crop production and larger food price increases, along with a slightly greater reduction in GHG emissions compared with the CC scenario. From this study, we are able to examine how the global economy responds when facing multiple pressures from rising food and energy demand under climate change in a more comprehensive and disaggregated manner than many previous studies. When designing policies, individual countries should take into consideration the overall costs and benefits associated with domestic energy, food security, and climate mitigation policy as well as the interactions of domestic policy with international policies.

### **Sustainable Agricultural Production in Least Developed Countries**

Michael Davidson, Davidson Consultants

Sustainable Agricultural Production (SAP)--also called Climate-Smart Agriculture; Innovative Irrigation Systems; and, Farming System Innovations, is implemented when growers draw from a tool kit consisting of instruments and methods to increase agricultural production by adapting to changing environmental conditions and by mitigating the deleterious environmental consequences of traditional agricultural regimes . SAP regimes are successful when all three conditions are fulfilled: yields and profitability increase, farming regimes are made adaptable to dwindling natural resources, and, agricultural fields are modified from carbon sources to carbon sinks with concomitant positive externalities. The tools of SAP consist of: water harvesting; ET-based irrigation; conservation tillage; run-off control; low volume/high uniformity irrigation; integrated pest and nutrient management; and, intensive agricultural production. This paper has three objectives: 1) to provide case-study evidence that SAP regimes can achieve all three objectives in Least Developed Countries (LDCs) and illustrate why this methodology has not been widely adopted. Yields have not increased significantly in LDCs over the past decade and environmental damage has not been mitigated; 2) to examine the interventions to correct perceived government and market failures in the agricultural sector in LDCs and provide evidence that, for the most part, these interventions were misguided, misdirected, and ineffective at increasing yields, providing adaptation incentives, and mitigation tools for farmers in LDCs; and, 3) to propose a new paradigm based on local knowledge and institutional capacity to achieve all three objectives in satisfactory temporal and spatial conditions. The urgency of developing an effective paradigm is illustrated by the following projections: the population of high-fertility countries is expected to triple, passing from 1.2 billion people to 4.2 billion between 2011 and 2100; by 2025 food production will need to increase by 45 percent; and, if traditional extensive farming techniques continue to expand, the percentage of global arable land under agriculture will grow from its current level of 36% to an unsustainable level of 60%.



### **Soils in the Water, Food and Climate Nexus: The Concept of Land Degradation Neutrality**

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"We recognize the need for urgent action to reverse land degradation. In view of this, we will strive to achieve a land-degradation-neutral world in the context of sustainable development." These sentences in the Rio+20 outcome document "The Future We Want" show that last year the world community in Rio realized that the protection of soil and land resources is a global task. This recognition is the result of a process that has been ongoing for decades but it's broader perception just evolved recently. The basic underlying drivers are of global importance. The demand for fertile soil is increasing as the world population grows and is moving up the food chain. Additionally, the demand for agricultural products is increasing since the bioenergy sector has entered the market. However the ecosystem functions soils provide to society go beyond the production of food, feed, fibre and fuel. On global level soils are the second biggest active carbon (after oceans). They store about three times more carbon than there is in the atmosphere. Furthermore soils store rainfall water and act as a natural filter for many substances found in water, including pollutants. This increasing demand for fertile soil meets a supply-side that is characterized by the fact that fertile soil is scarce, impossible to expand at short notice and prone to degradation, which means that they are losing the ability to provide the above mentioned ecosystem services to society. In the early 90s a Global Assessment of Soil Degradation (GLASOD) was performed, revealing that around 21% of all permanent pasture and 38% of all arable land is affected by human induced soil degradation. Around 9 million ha - an area bigger than Austria - is extremely degraded, meaning that they have been damaged beyond restoration. Worldwide about 296 million ha have been strongly degraded, meaning that major efforts (e.g. soil engineering or international assistance) are required to restore them. Even though the exact data of the assessment may be questioned, the report does provide a rough estimate on the status of soil degradation around 20 years ago. New and reliable data are rare, but it is expected that the situation has worsened since the GLASOD report. Similar to the drivers for an increased demand for fertile soils, the effects of soil degradation are of a global dimension. On-site effects of soil degradation contribute to food insecurity and limit rural development. The FAO estimates that 1.5 billion people (20% of the world's population) are directly affected by soil degradation. Furthermore, the off-site effects of soil degradation such as sedimentation of reservoirs and streambeds caused by water erosion and the carbon dioxide emission caused by soil organic matter loss do not stop at national borders. Therefore avoiding soil degradation and restoring degraded soils need to be addressed at a global level. The Rio+20 conference thus did well acknowledging that fertile, healthy soil is an important geostrategic resource. The Rio+20 outcome document uses the phrase "a land degradation neutral world". Land degradation neutrality implies that action has to be taken on both sides. On the one side land degradation has to be minimized and on the other side unavoidable land degradation needs to be offset by rehabilitation and restoration. Soils are in the midst of the water, food and climate nexus and play a pivotal role in meeting future demands for food and energy production,

water purification and carbon storage. Therefore, implementing the concept of land degradation neutrality within the Post 2015 Development Agenda is crucial in order to develop a coordinated global approach to protect this important geostrategic resource.

### **Crop Nutrition Increases Water Use Efficiency of Agriculture**

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More than two third of the world's freshwater consumption goes to agricultural sector particularly for crop production at its current state. Agricultural production has to be continuously increased in order to supply food and agricultural raw materials for the growing world population. Several projections indicate that agricultural production needs to be doubled to feed the world by 2050. However, this puts even further pressure on the scarce resources such as land and water. A strategy has to be sought to increase agricultural production without running into global water scarcity. The most reasonable means to meet this target is through sustainable intensification, the use of suitable means to increase crop production with less impact on the environment. Yield assessment of the world's major food crops indicate that there are huge gaps between observed yields and attainable yields in a given region. Closing the yield gaps is possible mainly through nutrient and water management (Mueller, et al., 2012). Some authors estimate that only about 15% of the rainfall or irrigation water is transpired by the crop for dry matter production. Most of the water used for irrigation is lost at storage and conveyance, runoff and drainage, and evaporation from the soil. These losses can be substantially reduced by employing efficient irrigation techniques and sound plant nutrient management. Crop nutrition enables better early growth and canopy cover which reduces bare-soil evaporation. In addition, well nourished plants develop vigorous root system which can take up water from deeper soil profiles and reduce drainage losses. Furthermore, optimal crop nutrition is essential for fundamental physiological processes such as light interception and photosynthesis, energy metabolism, as well as osmotic regulation. Therefore, optimally nourished crops are expected to produce more biomass per unit of transpired water than nutrient deficient crops. The presentation will show data on how best practice crop nutrition can improve crop yield and crop water use efficiency. Our research results indicate that nitrogen fertilizer increased grain yield and agronomic water use efficiency. In addition, the agronomic water use efficiency is positively correlated with yield across nitrogen fertilizer levels. About 600 liter of water was required to produce 1 kg of wheat grain at low nitrogen compared to only 380 liter under optimal nitrogen fertilizer supply, clearly indicating that optimum nitrogen nutrition increased agronomic water use efficiency. This implies that with proper nutrient management agricultural production can be increased with a given water supply without the need for additional land and water. This can be achieved especially in regions of the world where low crop yields are harvested due to poor nutrient management. Therefore, sound nutrient management is as an integral part of water management in agriculture and increases crop water productivity. Reference Mueller ND, Gerber JS, Johnston M, Ray

DK, Ramankutty N, Foley JA (2012) Closing yield gaps through nutrient and water management. *Nature* 490:254-257.

**Using index insurance contracts to hedge against water scarcity risk in hydropower production**

Ben Foster, University of North Carolina at Chapel Hill

Water scarcity reduces a hydropower producer's ability to generate electricity leading to large swings in revenues. These swings have implications for both energy utilities, in terms of revenues and/or costs, and consumers, in terms of prices (depending on the regulatory environment). In addition, generation and revenue volatility will get worse with increases in hydrologic variability, which is a predicted outcome of many climate change scenarios. Index insurance or weather derivative contracts have been proposed as a way to mitigate the revenue problem but the details of contract design, including the value of using both environmental and market models for design, have been glossed over. This study aims to show the methods by which contracts can be designed and their ability to mitigate risk in hydropower production (focusing on the electricity producer). As a result of short ramping times (i.e. speed with which generators can be turned on and off without efficiency losses) and low marginal costs, hydropower is an ideal and inexpensive source for meeting peak electricity demands and providing a variety of ancillary services necessary for smooth operation of the electric grid. As such it is a particularly valuable part of any electricity generation portfolio. Other energy sources, such as coal, nuclear, and natural gas, have either higher marginal costs, are not able to adjust quickly to demand, or experience significant efficiency losses when ramped up or down. Hydropower also has been shown to be an effective complement for maintaining system reliability and stability when other renewable sources (e.g. solar and wind) are introduced. However, hydropower production is dependent on water availability and therefore, vulnerable to highly variable hydrologic systems. In addition, reductions in generating capability are often correlated with peak electricity demands (e.g. summer months in the Southeast United States). This presents challenges for hydropower producers because variations in generating capability are financially disruptive for many reasons. If the hydropower project is part of an energy portfolio that is all or mostly hydropower, reducing volatility can lower the costs of capital, lower bankruptcy risk, and often increase share values for a firm. If hydropower is just a small part of a diverse generation portfolio, reduced volatility is effectively a cost hedge that stabilizes the whole portfolio's cost per unit of energy produced. This is similar in function to a futures contract for coal or other energy inputs. The financial impacts of water scarcity suggest a need for new approaches or tools as options for managing the hydrologic-based financial risks to hydropower producers. Whether an insurance tool that can reduce revenue volatility will be used depends on the regulatory and corporate environment of the firm. This study characterizes the financial risk faced by hydropower producers as a result of low water availability (i.e. supply risk) and develops several financial instruments designed to limit their exposure. A river basin model is used in concert with an electricity market model to develop and test the effectiveness of various contract structures, the most basic of which is index insurance. The basin model uses a 90-year dataset of synthetic stream flows on the Roanoke River in Virginia and North Carolina to

simulate reservoir operations, producing estimates of release schedules for a series of three hydropower facilities in the basin. Actuarial and financial pricing models are used to price the contracts. Results suggest that there are many tradeoffs when designing the contracts but that they have the potential to substantially reduce the financial vulnerability of hydropower generators to changes in water availability.

**Climate Policy as Water Policy: Water Quality and Conservation Co-Benefits**

George Frisvold, University of Arizona

This study examines how the proposed American Clean Energy and Security Act (H.R. 2454) would affect U.S. agriculture with special reference to water resources. The bill's cap and trade provisions for greenhouse gases would significantly raise fertilizer, irrigation pumping, and other energy-related costs. By 2030, it would reduce U.S. irrigation water use by >11% and fertilizer use by >18% with positive implications for water conservation and quality. Carbon offset provisions create financial incentives for farmers to sequester carbon by planting trees on cropland, reducing agricultural production and raising prices. Because sequestration potential differs by region, most of the estimated 51 million acres of converted cropland would be in the Corn Belt and Mississippi Delta. Afforestation would reduce Delta water use further, but increase water use in other regions compared to cap and trade alone. Compared to a no-policy baseline, irrigation water use declines 10% nationally, but increases in the Southern Plains. H.R. 2454 may have significant water conservation effects in some regions, but increase competition for water in others. By reducing fertilizer use and dramatically altering land use patterns in parts of the Mississippi Basin, it may also provide unexpected water quality benefits. Unintended water use and quality consequences of climate policies merit further research.

**Food producers at the center of the Water-Food-Climate Nexus: Implementing SHARP to increase climate resilience**

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Food producers and their resilience are at the core of sustainable development in the context of the water, food and climate change nexus. They are literally at the centre of the nexus and their decisions affect most aspects of the nexus every day, yet both in developed and developing countries they are not sufficiently aware of their role! Sharing tools for knowledge exchange and empowering farmers to understand their central role and its positive and negative implications, is at the heart of SHARP, a tool currently being developed at FAO. Family and smallholder farmers are key contributors to food production (43% of world food production) and the stewardship of ecosystems (over 97% of agricultural holdings) (FAO, forthcoming). Farming systems are more than just the sum of their parts. For instance in

rice farming systems there can be more than 100 aquatic organisms closely linked to rice production which creates a sustainable ecosystem and provides nutritious and diverse food (FAO, 2003; FAO 2013b). Although farming systems can positively contribute to sustainability, agriculture is also responsible for 70% of the world's freshwater withdrawals (OECD, 2010) and is a significant contributor to global GHG emissions - up to over 30% - through practices and land use changes (Barker, et al., 2007). Food producers are also heavily impacted by the effects of climate change (FAO, 2013a) and strongly influence the balance of local ecosystems and the global climate system as a whole through their actions. In the case of rice farming, the use of pesticides can significantly affect the level of aquatic biodiversity which in turn impacts nutrition, water quality and livelihoods of food producers and rural communities overall (FAO, 2003). While farmers' roles in the nexus are clear to many on an academic level - and some on the policy level - farmers themselves are often the least aware of them. It is thus imperative to empower farmers to better understand these linkages, not only for environmental reasons, but also as they strongly affect food producers' livelihoods. The first step must thus be to increase the awareness of food producers. Once food producers are aware of their role at the centre of the nexus, the next step is to provide them with the means to practice more sustainable and resilient food production. Increasing their resilience must be done in a holistic manner, leading to more efficient water use, fewer greenhouse gas emissions, higher adaptive capacity to shocks and higher incomes. Based on these principles, it is necessary to use a participatory approach to identify appropriate interventions, reflecting the specific agro-ecological and socio-economic contexts. The Self-evaluation and Holistic Assessment of climate Resilience of farmers and Pastoralists (SHARP) addresses this issue. This tool is currently being developed in collaboration with farmers and external partners and has been field tested in Senegal and Uganda. The tool is designed to be implemented with thousands of farmers and pastoralists in a participatory manner that includes surveys of practices and also aims to increase awareness of more resilient practices. SHARP is designed so that it can be implemented in any smallholder or agro-pastoral setting to ensure consistency. Questions are targeted in both a quantitative and qualitative manner. The qualitative portion encourages discussions and elaboration leading to the farmers themselves finding local solutions and forming partnerships. The information gathered will be used to identify weaknesses for improvement as well as to promote better practices. It creates an opportunity for food producers to learn about sustainable practices while at the same time providing invaluable on-the-ground information about their needs, vulnerabilities and success stories to policy makers to develop more targeted and informed programs. This iterative process enables policy makers, program implementers and farmers to work synergistically by empowering the farmers and sharing knowledge. Even when farmers are made aware of sustainability issues and empowered, there is still need for changes on the policy level to make sure there are no perverse incentives leading to undesirable practices. For example, although studies show that farmers in France could save money while contributing to climate change mitigation (Pellerin et al., 2013), they do not, indicating that a more enabling policy environment is needed. A consistent, comprehensive and global approach is needed to identify ways to improve food producing practices, through making food producers aware of their central position in the food-water-climate change nexus, empowering them to make informed decisions and creating an enabling policy framework.

**An investigation of water and energy efficiencies in optimized variable rate irrigation**

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The world's growing population and increased prosperity will increase global demand for energy, as well as food and water supplies in the coming decades. This together with the increasing energy demand in the water sector and vice-versa, an increasing water demand in the energy sector, calls for solutions that do not consider either aspect in isolation. Water use efficiency improvements in agriculture can effectively aid in alleviating food insecurity and poverty reduction. In addition, water use efficiency gains in agriculture can secure water resources for other landscape uses and ecosystem services. At the farm management level, growers look for greater profitability considering yield, energy and water usage, and fertilizer applications. Additionally, growers in many regions are facing restrictions on water usage, either through natural causes or governmental regulations. Growers are time-constrained and an integrated, easy-to-use optimized irrigation system would be of great benefit, particularly if it can be integrated with the other parts of their Farm Management Information System (FMIS). During extensive field measurements in Oregon, Washington and Idaho in 2013 both water use efficiency and energy use efficiency have been examined for various field crops under different management schemes and the relation between the two efficiencies has been investigated. The presented data are the results from a larger multi-year effort to demonstrate the effectiveness and profitability of an integrated irrigation management solution. The goals are to (i) obtain a more uniform, predictable yield, while also employing a deficit irrigation strategy, (ii) reduce the amount of crop water consumption without significant yield losses and (iii) optimize the irrigation energy requirements. The irrigation pivots were instrumented with variable rate irrigation (VRI) technology to allow for the collection of a comprehensive data set. The fields have been mapped for soil depth, soil texture, water holding capacity, and saturated hydraulic conductivity to account for the variability. The fields were instrumented with micrometeorological stations and neutron probe access tubes to estimate evapotranspiration, to measure rainfall and to measure soil moisture content. In addition to the environmental observations, the timing and intensity of irrigation was monitored through the pivot panel; water flow to the pivots was monitored with Doppler flow meters, and energy use (for water delivery) was monitored with via smart meters at high temporal resolution. These observations were used to drive an irrigation decision support system which provides optimized irrigation scheduling recommendations, based on the multiple information sources, when water supplies are limited. At each farm the optimized variable rate irrigation treatment is compared against 2 separate controls. The first is a uniform deficit irrigation strategy, and the second is the grower's standard practice. The experiment is replicated on 2 sites in the Columbia gorge region of Northern Oregon and Southern Washington. At the end of the growing season the spatial distribution of yield was mapped in the VRI fields and the SIS fields. The expected (simulated) yield variability, based on soil parameters of the VRI and control fields are statistically compared to the measured yield distribution. In this way, we directly assess if more

uniform, predictable yield, while also employing a deficit irrigation strategy can be achieved with VRI technology. Starting from field data the water use efficiency and energy use efficiency for current agronomic practices have been determined. We employed a simulation model to investigate a large number of known and improved agronomic management alternatives regarding water, crop and soil management and the potential improvement in terms of water use efficiency when choosing different management schemes. Lastly, cost curves based on the investigated management strategies have been derived as an additional means to evaluate the agronomic practice options. The simulation model proved to be a powerful tool that allows for the determination of best management strategies that can be used by a wide range of decision makers from farm managers to individual policy analysts.

**How might the Federal Government tackle multi-sector and multi-agency nexus challenges within today's budget and policy realities?**

Ron Hoffer, U.S. Environmental Protection Agency

The United States has made tremendous progress in addressing the nation's environmental challenges since the first Earth Day in 1970. The 40<sup>th</sup> anniversary of the passage of the Clean Water Act in 2012, for example, was a time to reflect on the dramatic improvement in surface water quality spurred on by the Act. Urban waterways have gone from wastelands to nuclei for redevelopment and connection of citizens with nature. Despite such progress, one-third of waterways in the US still do not meet quality standards, nutrient pollution from nonpoint sources have not been addressed to the same degree, and water quality will be further challenged by population growth. We will celebrate the 40<sup>th</sup> anniversary of the Safe Drinking Water Act this year, and there will be a comparable reflection on successes and work that remains.

The environmental programs in the U.S. have evolved largely on a media-by-media, and problem-by-problem basis. This "silo" approach may have been a necessary outcome of our evolving learning and regulatory tools, though unanticipated problems sometime emerged requiring yet another media or sub-media solution. Now, however, we are faced with issues that demand breaking down these barriers – issues that are at the core of this Conference. Despite the current budget and policy realities, Federal agencies like EPA have been seeking new ways to achieve broader sustainable outcomes. Examples of such approaches will be presented, and are reflected in: (i) EPA's new Strategic Plan focus on sustainability, (ii) interagency efforts to address climate impacts in the water sector, and (iii) targeted research and policy initiatives to accelerate sustainable utilities and cities. While many of yesterday's problems remain, tomorrow's world of increased risks demands both technological and institutional innovation. Environmental leaders are increasingly being asked to consider a wider set of concerns, and need to be resourceful and nimble enough to rise to the challenge.

**Impact of crop nutrition on the water footprint of agricultural production**

Brueck Holger, Yara International

The projected increase in food demand requires an intensification of cropping systems in order to avoid massive expansion of agriculture into natural ecosystems. Increased resource input (irrigation water) and inefficient farming practices (fertilizer doses and timing), however, currently present a burden to the environment because of regional exhaustion of freshwater reserves or non-point pollution of ground- and surface waters. Therefore, agriculture has to adopt measures to reduce the environmental impact, a concept often described as ecological intensification (Cassman, Proc. Natl. Acad. Sci, 1999). Impact of agricultural land-use on the environment is qualitatively and quantitatively described by several ecological indicators such as the carbon or water footprint and the nutrient use efficiency. The recently suggested water footprint is a quantitative indicator of water appropriation in the food sector. It enables policy makers, enterprises and stakeholders in the food and water sector to compare food production systems in terms of efficiency of water use and the impact on regional freshwater resources within a watershed. Pollution of freshwater by nutrients is considered as 'grey water' and defined as the water demand to re-dilute contaminated freshwater back to an accepted threshold value. The presentation will illustrate, in a case study with long-term trial data, the relationship between mineral N fertilizer application and grain yield of winter wheat and the related grey water demand. The economic optimum N application rate is generally similar to the ecological optimum N application rate in terms of grey water demand. This indicates that there is not necessarily a trade-off of between best-practice intensive agriculture and freshwater protection goals. However, economic and ecological optimum N application rates differ substantially between locations and from year to year, underlining the relevance of precision farming and site-specific nutrient management. N application above the economic N application rate induces a severe increase in the grey water demand making grey water demand ultimately to the most relevant item in the water footprint. Such inappropriate use of fertilizer increases not only the water footprint but at the same time it decreases fertilizer use efficiency.

**Self Supply. A promising option for water and food for millions**

Henk Holtslag, Connect International

The fast growing population in developing countries requires water for drinking, domestic use and irrigation. One option to increase access is scaling up Self supply which is possible with a range of existing and new low-cost technologies or so called Smart Water Solutions (SWS). These are simple and effective options that can be produced by the local private sector resulting in a "profit-based sustainability" and availability of spare parts. Water quality can be improved by hygiene education and treatment at the household level. Water quantity can be increased by upgrading existing hand dug wells or make new wells with manual drilling technologies. The new range of technologies include options to avoid collapsing of wells, recharge 500m<sup>3</sup> of rainwater in the ground at a cost \$ 10, hand pumps to 40



meters deep at a cost of \$ 50-150, House holds water filters of \$ 15-25 etc. With these options new wells can be made or a part of the some 4 million open hand dug wells in Africa that now dry up seasonally can be upgraded at a cost of \$100-500/well and count as a MDG7 water point. Some effects of SWS: ?Bolivia. Over 40.000 family wells made with EMAS and Baptist drilling. Cost of a 15-50 m deep borehole including pump \$150-400 ?Nicaragua. 70.000 Rope pumps installed. Total income increase with these pumps was \$100 million in the 12 years. Family incomes increased \$220/year.\* ?Zimbabwe. 8300 Siphon filters were disseminated during the 2009 Cholera outbreak. None of the families who used the filter reported cases of cholera. ?Tanzania. The shift from machine drilled boreholes and imported piston pumps to manual drilling and locally produced Rope pumps reduced the cost of water points from \$3000 to \$800. Now families buy Rope pumps for self-supply, and 95%, are functioning. Self supply differs from communal supply in that families or groups of families invest themselves in water systems. To reduce poverty it maybe more cost- effective to invest in self supply than in communal water supply and reasons to stimulate Self supply are: -Communal supply as usual will not reach all, the number of unserved in sub S. Africa increased with 66million since 1990!! -Increasing population and limited local funds and less aid families invest themselves -Reduces the "eternal headache" of pump maintenance - Self supply "automatically" becomes communal supply -Leads to productive use, more income, communal supply does not. Self-supply often becomes communal supply since families will get or buy water from their neighbors. Water near the house stimulates productive use for animals, irrigation etc. A pump in the garden "automatically" increases incomes as has been proven in Nicaragua and other countries. Income generated from a household pump often benefits women and families will maintain their own pump. Eventual problems with water quality can be solved with hygiene education and a 20US\$ household water filter. SMART Centres New affordable technologies are in place; the challenge now is large scale dissemination and that requires large scale capacity building. One option to do this is via so called SMART Centres which concentrate knowledge in one place, demonstrate new options and organise training in production, quality control, marketing etc. Many ttechnologies can be produced with local materials and the private sector can sell to NGOs but also private families. This creates employment and a sustainability based on profit so actions will go on after project funds stop. Experiences with the SHIPO SMART Centre in Tanzania after 6 years: ?20 Manual well drilling and pump companies trained ?4000 Rope pumps installed of which 30% Self supply ?Cost reduction of rural water points from \$40 to \$15 per capita Scaling up To scale up mayor fields of attention are: - Awareness. Create demand by information about the benefits and demonstration of SWS to families, NGOs, governments, others.. - Supply chain. Build up product supply chains of SWS by training local private sector in production, installation, marketing, management etc. - Financing. Provide payment options like micro credits for those who can not pay in one time. In short Self supply results economic development and so is promising option for water and food for millions.

**Efficient Water Management in NPPs: The IAEA Water Management Programme (WAMP)**

Ibrahim Khamis, International Atomic Energy Agency

Availability of water resource is one of the important factors affecting the siting and economics of a nuclear power plant. Based on current cooling water requirements of a generic 1000 MW(e) nuclear power plants, units with once-through cooling would require about 26-64 m<sup>3</sup>/s. Technological advances in the design and operations of a nuclear power plant aiming at reducing water use and consumption can have a positive impact on the attractiveness of nuclear power and its benefits. As water and power are inseparably related, it becomes clear that the availability of one will affect the availability of the other. The optimal choice will require knowledge of the available options. A bulk of countries considering introduction of nuclear power are in water scarce regions. Moreover, recent experience has shown that nuclear power plants are susceptible to prolonged drought conditions, forcing them to shut down reactors or reduce the output to a minimal level. In some cases, it has been a developing environmental issue that resulted in regulations which limit the possibility for water withdrawal as well as water discharge. Reducing the water use and consumption for nuclear power plants is likely to help such countries in introducing nuclear power in their energy supply mix. Providing available options and guidance will help especially newcomer countries considering embarking on nuclear power in their decision-making for water management strategy. As water and power are inseparably related, it becomes clear that the availability of one will affect the availability of the other. Management of water at nuclear power plants is an important subject during the entire phase of construction, operation and maintenance of any nuclear power plant. Water management addresses the issue of securing water for condenser cooling during operation, for construction (during flushing phase) as well as inventory control including makeup to primary coolant system and discharge from radioactive liquid waste treatment system. Providing available options and guidance will help especially newcomer countries considering embarking on nuclear power in their decision-making for water management strategy. The IAEA has developed and released the Water Management Program WAMP, and made it freely available to all Member States. WAMP can be used for the estimation of water needs in NPPs especially for water cooled nuclear power plants as it estimates both the needs for cooling water and other essential systems, and helps in the selection process of cooling systems by evaluating three different criteria: Water resources, environmental, economical. The paper will discuss some issues and possible solutions for efficient water management in NPPs and provide an overview of the IAEA Water Management Program.

**Sustainable intensification in Mixed Crop-Livestock Agro-Ecosystems: The case for the Guinea Savannah Zone of in the Volta Basin of West Africa**

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In 2012, on-farm trials were conducted in Tamale and Lawra districts of Ghana. The trials entailed 5 treatments of maize-soybean intercrops each with 3 replications composed of varying fertilizer, manure and soil-water conservation methods that were monitored on a real-time basis to deduce the progression of the soil moisture regime. The three factors that were selected as variables were: manure, inorganic fertilizer and the type of tillage. The soil texture for the Tamale site is a loamy clay soil with a friable structure while the Lawra site is a sandy loam soil with coarse stone aggregates. Soil textural differences revealed varying soil moisture storage regimes and had an impact on the structural durability of the in-situ soil-water conservation interventions. We surmise a facilitative and complementary co-existence between maize and soybean with no evident competition due to differences in crop phenotype and growth stages. Soybean water productivity ranged from 0.12 kg/m<sup>3</sup> in the control treatments to 0.2 kg/m<sup>3</sup> for treatments with no fertilizer but with 40 kg of manure application under tied-ridging (NFM40R). Maize water productivity estimates from both sites in this study ranged from 0.5 kg/m<sup>3</sup> for treatments with no fertilizer with 40 kg of manure application under contour bunds (NFM40C) to about 1.2 kg/m<sup>3</sup> for treatments with fertilizer and 20 kg of manure with tied ridging (FM20R). Maize revealed a higher seasonal ET average (13%) than soybean. For both sites, soil moisture storage was consistently higher for treatments that had fertilizer with 20 kg manure under tied ridging (FM20R). Maize water productivity and gross value of production trends at both study sites was in the order: FM20R > NFM40R > Control > NFM40C while soybean was: NFM40R > NFM40C > FM20R > Control. These productivity trends are attributed to the combination of captured water, manure-fertilizer dosage supplements and soil conservation. The rain water that was captured within the ridges serves as a "micro-storage basin" thus providing more residence time for the water to infiltrate into the profile. The combination of tillage types with inorganic and organic supplements will yield appreciable dividends for maize and soybean. If both crops exist as an intercrop, we recommend a judicious combination of interventions that improve moisture retention and the nutrient status for optimal crop responses depending on soil textural attributes. Previous work has reported that water productivity of rain-fed agriculture in the Volta Basin tended to increase as rainfall decreased (Lemoalle, 2008). This is consistent with findings in this study where rainfall in Tamale was lower (614 mm) than that in Lawra (694 mm) yet the crop water productivity and gross value of production was higher in the latter than the former. The notion of water productivity being lower in wetter areas than in drier areas has also been cited elsewhere. For example water productivity in irrigated areas in the Karkheh Basin, was lower than in rain-fed areas (Ahmadab et al., 2009). Water productivity in these systems is also largely driven by factors affecting land productivity, for example, crop production technology, input use and post-harvesting processes. Improvements in the rain-fed systems, coupled with investment in fertilizers and small-scale irrigation, offer the main opportunity for development. Other positive measures include improvements in infrastructure, secure and transparent land tenure, access to agricultural water and affordable micro-credit. The work conducted herein highlights that the technical possibilities for improvement have been well identified, but the social and economic conditions for their implementation need further emphasis and careful institutional and socioeconomic appraisal. In the Volta basin, for example, the duality between the legal state and the traditional hierarchy impacts a

number of social determinants such as land tenure and access to water. In addition, this research has the potential to be replicated in parts of Western Kenya and the Tana River basin in Eastern Africa.

**Implementing the nexus approach: the challenge of multi-scalar cross-border collaboration**

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Water, energy and food (WEF) security are pivotal components of climate change adaptation (CCA) at multiple scales. Approaching CCA through a WEF nexus lens yields considerable potential for the development and implementation of integrative, holistic and sustainable measures. Essential to this is the recognition that environmental and other shared issues transcend urban-rural divides and thus require collaborative development and management. Nexus approaches commonly apply systems perspectives and system wide approaches to planning and decision-making where the strategic resources that comprise the nexus are considered in an interconnected multi-scalar manner. Effective CCA requires collaboration between bordering and distant local governments to support the expansion and conservation of vital ecosystems beyond administrative boundaries and support cross-border CCA of key socio-ecological systems. For example, if a specific region or municipal area is dependent on upstream water resources it is essential that the various authorities involved collaborate and manage their ecosystems appropriately to avoid cross-border water shortages. Ecosystem services are now strongly promoted within the broad climate change literature as essential elements of mitigation and adaptation strategies and is a rapidly growing WEF nexus research area. However, notwithstanding these factors, together with the widespread recognition that urban and rural systems and the livelihoods of people within these are intrinsically connected, research on CCA has tended to focus on these systems separately. This paper seeks to address this gap by considering the role that a nexus approach to climate change governance can play in explicitly highlighting and supporting the need for genuine cross-border collaboration among local governments and other key stakeholders to support WEF security and other key environmental concerns. The paper draws specifically on recent research in South Africa's greater Durban metropolitan area and considers facilitators and barriers to a WEF nexus framing for CCA. Durban municipality is a particularly interesting and revealing case study for considering the WEF nexus and ecosystem approaches since the municipality is a leader in implementing the ecosystems services approach through their innovative Durban Metropolitan Open Space System (D'MOSS) - a network of protected land and water bodies that constitute 'green infrastructure' for the region. Despite the effectiveness of D'MOSS the approach has incurred significant challenges, including local acceptance and cross-border expansion difficulties. The paper considers these and other challenges of cross-border collaboration among local authorities with divergent constituencies and perceived interests and reflects on implications for a nexus approach to CCA and planning across borders. While the findings are specifically related to the South African context, they are more widely applicable in developing and developed contexts.

**Trade-offs for whom? Examining the winners and losers in the Mekong Basin Hydropower Expansion**

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This paper examines the challenges and opportunities that hydropower development in the Mekong Basin presents within the water-food-climate-energy nexus. The paper analyses why powerful actors often benefit from the Mekong's rapid hydropower development while vulnerable groups and environment are negatively impacted. The Mekong Basin is rich in biodiversity and home to approximately 70 million people many of whom rely on the ecosystem services for their livelihoods and food security. The Basin is also currently experiencing rapid social, economic and ecological change. Hydropower is a key component. The paper employs a political ecology approach to critique the narratives, mechanisms, and power relationships and agendas that drive and enable the current phase of hydropower development. Using a meso-scale analysis the paper will highlight the links between water, food, climate and energy by analysing the political, economic and social mechanisms, macro-political economic forces and local level environmental and social change. Recent and current phases of hydropower investment and development over the last two decades will be discussed. The paper draws from over three years research on the ground, including interviews, document analysis and participant observation, carried out across the Basin from 2010-2013. Evidence from case studies is employed including examples from the Xayaburi dam, the first mainstream dam in the Lower Basin. Through its analysis the paper provides evidence of the mechanisms and narratives that drive and enable the differences between the rhetoric and reality of hydropower development in the Mekong Basin. The paper shows that the polarized debate surrounding hydropower and its impacts on the water, food, climate and energy nexus, the outcome of which is so important for the future of the Mekong Basin and its peoples, has been constructed to allow contending actors to legitimize their own agendas. The paper will conclude by offering suggestions for how hydropower development may be improved using nexus thinking.

**Offshore Wind Energy: The Solution To Conventional Electricity Production's Impact On Water Health**

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Many have touted offshore wind energy's environmental benefits; however, one often overlooked is improvement in water body health. Conventional electricity production consumes excessive amounts of water for cooling purposes, discharges water that contains biocides and alters natural water temperature and dissolved oxygen content, and impacts fish populations through impingement and entrainment of fish. Wind energy, when replacing conventional electricity, eliminates these externalities. The integration of wind energy in place of conventional electricity sources can conserve ecosystems and water resources in addition to providing savings to commercial and recreational

fisheries. Future policies could be created to account for these benefits and incentivize offshore wind energy. This analysis focuses on the water health externalities caused by electricity production in the Delaware Bay. In the U.S., thermoelectric plants withdraw 49% of the total water withdrawn, which amounts to 201 billion gallons a day. This exceeds all other uses such as irrigation and industry, and thermoelectric plants use this water for free or little cost. Considering water use in the Delaware Bay and assuming that water has the value of wastewater at the modest rate of \$1,000 per million gallons withdrawn, electricity plants in the Delaware Bay use \$97.25/MWh on average. The withdrawal of water also causes impacts to fish populations. The U.S. Environmental Protection Agency estimates that annual impingement and entrainment in the Mid-Atlantic kills the equivalent of 990 million 1-year-old fish, which is an estimated loss of \$3 million to commercial fisheries and \$26 million to recreational fisheries. Considering the commercially important species of weakfish, Atlantic croaker, and striped bass alone, power plants in the Delaware Bay cause nearly \$2 million loss to commercial fisheries annually. Thermoelectric plant's excessive use of water eliminates fish and disrupts habitat, and this impact is rarely accounted for in the market. This water impact externality demonstrates market failure. Policies could encourage wind energy development if these damages caused by conventional energy were monetized and taxed or mitigated through tradable permits. This provides a new perspective for public education and outreach about the water-energy nexus. Stakeholders such as fishermen, agricultural groups, and environmental activists may support policies to compensate for these water health externalities. These groups may support wind energy in light of these benefits. In addition, the uncompensated consumption of water and loss of wildlife can be seen as a violation of public trust. In conclusion, the often ignored impacts of electricity production on water could illuminate wind energy's benefits and encourage growth of sustainable energy production.

**Index insurance and water scarcity: managing financial risk in commercial shipping on the Great Lakes**

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The Great Lakes system in North America has shown declining lake levels and changing seasonal flow regimes in the past 10-15 years. The Great Lakes system is the largest freshwater resource in the world, and cargo handling and transportation service companies from the U.S. produce billions in revenue each year shipping coal, grain, and other bulk goods. The changing inflow regime seen in the recent past may be indicative of the effects of climate change, but regardless, the inflow regime has large impacts on the various energy and food industries and economic activities that depend on the Great Lakes. Low and uncertain lake levels can significantly affect the revenues of shipping companies, as a ship's cargo-carrying capacity depends on its "draft", or the distance between the water level and the bottom of the ship's hull. A ship's draft increases with the weight of its cargo load, and lower lake levels force ships to reduce their loads in order to ensure that a ship does not run aground. As low lake levels translate to lighter cargo loads and lower revenues, these hydrologic variations have a direct financial impact on

shipping companies. Financial tools, whether designed as insurance or some other form of risk transfer instrument, can provide adaptable methods for managing the economic impacts of water scarcity. Such instruments, most notably flood insurance products, have proven effective in managing financial risks at the other end of the hydrologic spectrum, but much less investigation has been undertaken with respect to drought-related tools. One potentially valuable tool is index insurance, a contract in which the premium-payout structure is determined by the behavior of natural systems whose state can be reliably measured, through the use of an index (e.g., rainfall, temperature). The challenge in developing such products is two-fold, first the index and a particular financial risk must be reasonably well correlated (low basis risk), and second, a contract must be developed that can mitigate the financial risk in a meaningful way. A relationship between lake levels and shipping revenues for different sized vessels was developed and validated with other cost models on the Great Lakes. An actuarial analysis of the frequency and magnitude of financial risks faced by commercial navigation during times of low lake levels was completed using this relationship and a 55,000 year stochastic dataset for lakes Superior, Michigan-Huron, and Erie. This actuarial analysis of the magnitude and probability of risks was then used to develop a novel set of index insurance contracts with different structures (e.g., options, collars). The optimal structure and length of contract was determined by limiting basis risk and contract cost, using simulations of the contracts over the historic dataset of levels for each lake. The pricing of these contracts, a non-trivial endeavor, is also explored using methods from other applications of index insurance, including agriculture and energy. Finally, several methods for implementation of these contracts are explored.

### **A Critical Review of Long Term Water Energy Nexus in India**

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Water and energy are the two most essential resources for the survival of human beings on this planet. Over a period of time, due to rapid population growth, the introduction of complex industrial processes and rapid agricultural growth, both water and energy have become exhaustible resources. Consequently, sustainable development will be challenged because access to these resources and their sustainable management are the basis for sustainable development. Therefore these resources now require careful attention in the context of their extraction, use and disposal. As a matter of fact water and energy are inherently inter-linked and inter-dependent. The insecurity of each of the individual resources is also aggravated when they are considered together. The challenge of thinking in a nexus perspective is central to the Green Economy, to the themes of Rio2012 and the consideration of sustainability development goals (SDG). Understanding this fundamental principle of interdependence, we have tried to investigate the scientific relationship between these two resources in the context of energy generation and subsequently the long-term consequence of water constraints. There are ample studies available where the relationship of energy use in water extraction, distribution and consumption

has been investigated. But the upper cycle of the relationship, where water is an essential input factor for energy generation, has hardly been investigated in a scientific manner. Though there are a few studies available on a global scale, which have mostly been done based on information collected from the United States, there is no such study available for regions in Asia. Understanding the requirements of such an important assessment, we conducted case study in India, to demonstrate the impacts of water scarcity on long-term energy supplies up until 2050. India is a major economic hot spot in Asia, and has an enormous appetite for energy, but with limited water resources, the country poses an excellent case study for us to investigate the impact of potential water scarcity on the long-term energy supply situation. To meet the objectives of this study we depended on several tools such as a literature review, power plant survey, stakeholder consultation, and water adjusted MESSAGE model, an energy system model. We relied on available literature for analysing the state of water resources in India. Power plant survey was conducted to estimate water use intensity of different types of power plants. We used MESSAGE model to obtain an integrated assessment output. In India where per capita water availability has dipped below the alarming threshold of water stress (below 1700 m<sup>3</sup>), water intensive thermal power plants form the backbone of national power supply by contributing almost 60% of electricity generation in India. Indian power plants are high in water using, ranges 2.8 m<sup>3</sup>/Mwh with closed loop cooling system to 160 m<sup>3</sup>/Mwh with open loop cooling system compared with global average (1.2-1.5 m<sup>3</sup>/Mwh). Geographical distribution of existing thermal power plants shows that more than 75% of these are set up in either water scarce or water stressed regions. The dominance of coal-based thermal power generation in the total electricity supply mix of the country is not likely to change due to availability of abundant coal reserves. This instigates exclusive need of water for electricity generation that will intensify conflicts among sectors of water use. On the other hand, trend of intensifying water scarcity may put the operational continuity of power plants in jeopardy. To minimize potential damage, India's Ministry of Environment and Forests (MoEF) banned the construction of TPPs with OLW cooling systems in June 1999. We have therefore estimated two different water demands based on both the pre-1999 and post-1999 regulatory situation. It indicates that if India were to continue pre-1999 open loop wet cooling system, the country would require a maximum of 227 billion cubic meters (BCM) of water per year just for thermal power generation by 2050 which would be 20% of the total utilisable water in the country by that time. However, with policy intervention that huge water demand could be reduced to around 85 BCM per year for electricity generation by 2050. Under water constrained conditions, the energy system model behaves conservatively and deploys technologies which need less or no fresh water. As a matter of fact, sea water cooling in gas technology becomes predominant in this case. It has been observed that unless there are alternative technologies available to mitigate the impact of water scarcity for electricity generation, the system also fails to meet the required energy demand. As a matter of fact, water availability is absolutely critical to maintain the balance of energy supply and demand in the market.



**Water-Energy Nexus: Implications of Sustainable Water Management in Coastal Regions under Rising Water Scarcity**

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1. Introduction Increased water demand, scarce freshwater resources, and stricter regulations on wastewater discharge requirements have forced coastal municipalities to seek non-traditional water sources. While energy intensive desalinated seawater and brackish water supplies are being developed widely and swiftly, water reclamation is still far below its full potential, particularly in coastal regions experiencing water supply constraints. To understand the current management dilemma between constrained surface and groundwater sources and potential new water sources, there has been a proliferation of life cycle studies on water and wastewater systems and the management implications associated with their impacts. Only a few of these life cycle studies, however, included water reclamation, and inconsistent system boundaries were adopted in these studies. Furthermore, region specific conditions, such as local water resources, grid mixes and topography have also been mostly neglected in previous studies. Hence, the present study aims at understanding the implications of different water management strategies using case studies from Tampa, FL and San Diego, CA. They were selected as case studies not only because of their coastal locations and rising contradictions between water demand and supply, but also because of their similar population, land area, economy, and water consumption characters. 2. Methodology The Tampa Bay Water Planning Region (TB) and the service area of the San Diego County Water Authority (SD) are both coastal water scarce regions experiencing rapidly growing water demand, driving the need to vigorously developing alternative water supplies. To understand the impacts of future water management strategies, three scenarios were proposed for each study area: 1) maximize traditional supplies; 2) maximize seawater desalination; and, 3) maximize non-potable water reclamation. Three types of impacts were assessed in this study: embodied energy (i.e., direct and indirect), GHG emission and energy cost. System boundary includes the operation, maintenance and construction phases of the anthropogenic water cycle (water supply, wastewater treatment, and water reuse). Embodied energy was either estimated through an input-output-based hybrid approach, or obtained from recent literature. GHG emissions and energy costs were estimated based on embodied energy values and local grid composition. 3. Results and Discussion A comparison of water infrastructures in SD and TB shows that most of the SD systems have generally higher embodied energy and energy costs than the TB systems, especially in terms of seawater desalination and water reclamation. GHG emissions, on the other hand, are lower in most of the SD systems except for water reclamation, which exhibits a relatively smaller gap between the two regions compared with energy consumption. This is the result of the higher non-fossil fuel contribution to the electric grid in SD. Maximizing water reclamation as a future water management strategy can be better than either increasing traditional supply or seawater desalination in both of the studied regions in terms of energy consumption, GHG emission and energy cost. Furthermore, while shifting to renewable energy sources

can significantly reduce GHG emissions; it is still restricted by the water sector's dependence on the fossil-fuel-based upstream industries, such as transportation, and steel and cement productions. To resolve this problem and further reduce GHG emissions, strategies such as electrification (replace gasoline with electricity in cars, for example) as well as energy efficiency improvements of the fossil-fuel-based industrial sectors have to be implemented. In addition to grid mix changes, water conservation is a potentially more efficient strategy to achieve similar GHG emission reductions with less financial investments.

### **Water quality effects of cellulosic biofuel crops grown on marginal land**

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In the Energy Independence and Security Act (EISA) of 2007, Congress set goals to increase Renewable Fuel Sources by 2022, a portion of which are expected to come from cellulosic biofuel crops (Congress, 2007). This increase in crops and use of new crops calls attention to environmental consequences, including water quality. Second generation biofuels such as perennial grasses, like switchgrass and Miscanthus, and woody plants, such as poplar and willow trees, can provide an alternate to the traditional crop of corn and soybean, however their effects on water quality are not well studied. The main objective of this research is to determine water quality effects of growing different biofuel crops on marginal lands. This research is focused on quantifying surface and subsurface nutrient losses and sediment runoff. The samples are collected from the Throckmorton Purdue Agricultural Center (TPAC), just outside of West Lafayette, IN. Surface water samples are collected in tanks at the bottom of sloping land, while subsurface water samples are collected using 12-inch suction cup lysimeters. We plan to present preliminary data demonstrating nutrient losses to surface and subsurface waters, as well as soil erosion losses. This data will be used to determine on a field-scale level the possible water quality impacts of these crops as well as helping determine impacts of the increased demand.

### **Standard-izing the Nexus: certification's role in tackling food-energy-water**

Alexis Morgan, WWF-US

One of the key ways in which corporations have responded to the emergent sustainability challenges of the past 20 years has been through standards and certifications. Such best practices, backed by 3rd party auditing, have enabled numerous commodities to begin to differentiate based on more environmentally and socially responsible production methods. The growth of such standards has been considerable and in many cases now represents a material percentage of global production (e.g., 12% of global timber to Forest Stewardship Council, 29% of global whitefish production to Marine Stewardship Council, 12% of global palm oil production to Roundtable on Sustainable Palm Oil, etc.). The majority of

these systems emerged along commodity-lines (food and materials) with some considerations for carbon, energy and water. However, as the notion of shared risk has emerged, many standard systems have lacked the necessary requirements to adequately address the complicated systemic tradeoffs that emerge when tackling nexus challenges. However, increasingly, the standards community is beginning to think about the challenge that the nexus poses to many "food focused" standards and consider systems of standards that address the complexity that comes with the nexus. This session will begin by exploring the current gaps in a number of standards when it comes to nexus issues from a water perspective. It will also highlight the gaps with respect to the scope of responsibility and the lack of governance mechanisms necessary to address such integrated challenges. Beyond identifying the gaps, it will explore, through case studies from the Alliance for Water Stewardship and Rainforest Alliance and ISEAL, the cutting edge of practice in attempting to develop integrated systems that can optimize such challenges while still working for corporate and other audiences. Lastly, through an interactive discussion with a panel and the audience, the session seeks to explore new ideas in how standard systems, together with corporations, non-governmental and public sector agencies can work to build new ways of ensuring social and environmental standards continue to help, rather than hinder, our ability to tackle the nexus.

### **World Vision's Integrated approach to sanitation and water supply transforms post-war communities in Northern Uganda**

Francis Mujuni, World Vision

World Vision has been operating in Uganda since 1986 to respond to the needs of people after the National Resistance Army (NRA) war that ushered in the National Resistance Movement (NRM) government led by President Yoweri Museveni. World Vision implements child sponsorship programs in 53 area development programs (ADPs) in 41 districts, including Northern Uganda that was affected by the Kony war. The 20 years of terror destroyed the core values of hard work, independence and self-reliance. People had lost hope and depended only on government and humanitarian agencies for the protection of their livelihoods. After the war ceased in 2006, World Vision and other agencies embarked on resettlement, rehabilitation and re-integration of former internally displaced persons as well as formerly abducted persons. High expectation of hand outs and relief from government and non-governmental organizations has been a great challenge to addressing development issues in these communities. However, the introduction of Community-led Total Sanitation (CLTS) as part of the integrated approach to the provision of water in rural communities is beginning to yield some dividends. CLTS is a powerful mobilization tool to ignite other key development initiatives like food security, improved livelihoods, water resources management and disaster risk reduction programs. World Vision adopted CLTS as a methodology to re-invoke people's resiliency amidst problems of survival and development, beginning with construction of their own latrines using their own resources and without any external subsidies. Gwenglik is one of dozens of communities that have shown such personal and community improvements through CLTS. It is in the eastern part of Gulu district. Gwenglik has 75

households with 315 people. In June 2011, World Vision identified Gwenglik as one of the communities with low latrine coverage, poor sanitation and no access to safe and clean water. World Vision's staff and local government staff started off by applying the CLTS methodology. The village attained an open defecation free (ODF) status in May 2013, and, through their own initiative, raised money and personal resources to support the construction of a borehole to provide accessible, clean water to their community. This has improved health and increased resiliency, as shown through other self-help initiatives. They opened up a community garden to cultivate maize and vegetables as an income generating activity and put up their own vegetable gardens to improve the nutrition status of their families. Community members have also planted grass around the borehole and trees in the catchment area to stop runoff water that causes soil erosion and to beautify the environment around their borehole. World Vision Uganda hopes to use the good examples from this community in Northern Uganda to address the challenges of climate change, food insecurity, malnutrition and ill health through water security and community empowerment.

### **The economic benefits of multiple uses of water**

Emmanuel Opong, World Vision

Many rural communities in developing countries face the challenge of access to sufficient and reliable water for multiple uses ranging from drinking, food production, income generation, hygiene and sanitation, which would otherwise enable them to be food and income secure. Hamasamu and Hamunyanga communities in Southern Zambia were no exception. Lack of access to productive water kept the two communities in vicious cycle of poverty for a long time. Over the years, the communities experienced serious water stress and crop failure resulting in child malnutrition above 68 per cent. Lack of employment opportunities and income led to prevalence of HIV and AIDS and a high school drop out rate. While all this was happening, thousands of litres of water were available from a nearby spring. This sad reality triggered World Vision International (WVI), in partnership with the communities and the government, to develop the spring into a multiple use system that would cater for domestic and productive uses in order to improve livelihoods and contribute to the well being of the two communities. A study aimed at assessing the economic benefits of multiple uses of water in Hamunyanga and Hamasamu communities of Southern Zambia was carried out in July 2011. The assessment methodology involved 12 key informant interviews with the community leadership, technical staff from the government of Zambia's line ministries -- Agriculture, the Department of Water Affairs; local government; health; and World Vision project staff on what they perceived to be the economic benefits of the project. Community focus group displays and performances through drama, narrations and songs were also used as sources of information. Six focus group displays were conducted. Focus group discussions with children, women and men were conducted including a mixed group narration, play and song display. Field assessments and verification of the irrigation plots, crop assessments, farmers' yield and sales records also formed part of the inquiry. Data analysis was done by developing themes based on the indicators, and then finding patterns, relationships and connections

between them which were then used for interpretation of the findings. The themes included; food productions, local employment generation, produce pricing regimes and income generation. The assessment showed that access to domestic water improved from an average of 10lc/d to well over the recommended 20lpc/d. Walking distances improved from an average of 500m one way trip per household to as low as 5m one way trip for over 95 per cent of the households. Time spent on collecting water had reduced from an average of 1 hour to less than 10 minutes. The access to water for crop production and other productive uses created employment opportunities for 95 per cent of households -- mostly women (World Vision News, Nov. 2011). The access to irrigation had also generated employment opportunities for 25 per cent of the school drop outs. Increased crop production has led to improvement of the nutritional status of the under- fives from 68 per cent malnutrition in 2007 to 42 per cent malnutrition in 2011 (Government of Zambia, Ministry of Health).

### **Mekong Dams- Water, food and energy collision**

Stuart Orr, WWF International

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Proposed dam construction in the Lower Mekong Basin will considerably reduce fish catch and place heightened demands on the resources necessary to replace lost protein and calories. Additional land and water required to replace lost fish protein with aquaculture products are modelled using land and water footprint methods, complementing an earlier analysis for replacement using livestock. Two main scenarios cover projections of these increased demands and enable the specific impact from the main stem dam proposals to be considered in the context of basin-wide hydro-power development. Scenario 1 models 11 main stem dams and builds on livestock estimates of a 4-7% increase overall in water use for food production, with much higher estimations for countries entirely within the Basin: Cambodia (29-64%) and Laos (12-24%). Land increases run to a 13-27% increase. In scenario 2, covering other 77 dams planned in the Basin by 2030 and reservoir fisheries, projections are much higher: 6- % for water, and 19-63% for land. Modelling covers the footprints of aquaculture for specific fish species to estimate land based resource requirements as well as policy, investment and access issues. This analysis emphasizes the responsibility of governments to articulate strategies and trade-offs to ensure basic food security where protein supplies are at such a high risk of disruption from dam developments.

### **Climate Change and the Energy Industry: Water Used in Hydraulic Fracturing**

Heather Payne, UNC Center for Law, Environment, Adaptation, and Resources

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Water is becoming less available, with water use increasing and the number of people exposed to water scarcity or water stress increasing as well. Climate change is making this worse. However, the mechanisms put into place to manage scarcity in a water-constrained world will have significant impacts on human populations, agriculture, energy and the environment. Looking first at current water projections and how water is utilized today, energy production – and specifically the production of electricity by thermoelectric plants – is the largest single user of water. This is followed by irrigation and then by public supply. While hydraulic fracturing currently uses less than 1% of the water used in the United States annually, it is different from all other uses, even other consumptive uses, because the water used in hydraulic fracturing is designed to be permanently removed from the hydraulic cycle.

Hydraulic fracturing is a process by which shale rock is fractured with a solution between 98% and 99% water. Each well, depending on the shale play, requires up to six or eight million gallons of water – in a period of 3 to 5 days. This water is removed from the hydraulic cycle either by staying permanently sequestered in the well or by being disposed of in an injection well. And this affects much of the United States – shale plays using or likely to use hydraulic fracturing are located in 33 states. In Pennsylvania alone, close to 40 billion gallons of water have already been removed permanently from the hydraulic cycle. One way to address this is by recycling, but little recycling is currently occurring; for example, less than 5% of water is recycled in the Eagle Ford shale in Texas. Given the low reuse rates, energy production companies who use hydraulic fracturing need future access to water. To minimize the cost of transportation, they prefer surface water or groundwater sources close to drilling sites. Others are looking at pipelines, sometimes from municipal water systems. Regulations do not treat hydraulic fracturing differently from other uses. New regulations which treat this permanent consumptive use differently will be necessary to affect behavior to ensure water use minimization.

Traditionally governed by state law, water allocation decisions vary based on policy and location. The Marcellus shale, located in New York, Pennsylvania, Maryland, Delaware, New Jersey and West Virginia has water withdrawals governed by two interstate river basin commissions and varying degrees of state regulation. Texas, another location with several developed plays, has developed more than 33,000 new natural gas wells since 2005 using 110 billion gallons of water during that time. Texas has also been suffering from a drought, pitting farmers, electricity production, and cities against each other. However, for groundwater withdrawals, Texas law statutorily-exempts wells used to supply water for drilling or exploration operations for oil or gas. Other plays around the country have similarly sparse water procurement regulations.

A possible regulatory scheme which would more adequately value water in a constrained world is curtailment. Under a curtailment regime, use of water for hydraulic fracturing activities would cease if certain conditions, such as passby flow minimums or drought triggers, were met. By knowing at what point curtailment will occur and how it will occur, the energy extraction industry will have certainty. It could also spur development of techniques for recycling and non-water fracturing. These regulations should be adopted at the state level. By adopting a curtailment regime now, even as the American

economy becomes more energy-dependent, the environment is less likely to be the loser when shortages do occur.

**Food, Water, Energy and Climate: Integrated Simulation Models to Support a Shared Understanding of the Nexus**

Matteo Pedercini, Millennium Institute

The interconnectedness of our food, water, and energy systems among themselves, and with the broader climate system has always existed. Nevertheless, until the very recent past such relationships did not fully manifest themselves at the global scale, due to the abundance of natural resources compared to the size of human population. Globally, the abundance of resources absorbed as a buffer the relatively small shocks that each system generated locally. Recently, the chained food, energy, and economic crises have begun to highlight the strength of such interconnectedness at the global scale, and the reduced buffering capacity of our natural systems. The inherent complexity and integrated nature of such systems make it difficult to observe and interpret them, thereby limiting the ability of decision makers to design, implement, and evaluate effective strategies and policies. This limitation is at the root of development failure, where policies have created unexpected, often-undesired results. Well-intentioned policies addressing the symptoms of a problem often only create short-term benefits that are defeated by the longer-term reaction of the system, resulting from the interplay of forces that go beyond the narrow boundary of the area of intervention. For example, policies designed to promote food security such as intensifying agriculture, developing more agricultural lands and intensive irrigation systems, applying chemical fertilizer and pesticides; have resulted in unintended and unexpected challenges such as land degradation, depletion of water aquifers, vulnerability to crop failure, and eventually continuing or even increased vulnerability to food shortage, thereby aggravating food insecurity. Integrated simulation models support a broader understanding of the nexus, thus enhancing the ability of decision makers to design and evaluate development policies. Integrated simulation models mimic the critical aspects of the real system, so that its behavior can be studied. In other words, they are laboratory replicas of the real system that can be used to perform policy experiments that are impossible in the real world. By bringing together the social, economic, and environmental aspects of development in one framework, integrated simulation models allow for broad, cross-sector and long-term analysis of the impact of alternative policies. Better policies can be thus designed, simulated, evaluated, implemented, and monitored over time. Over the last two decades, the Millennium Institute has developed a variety of integrated modeling tools to support national development planning through a multi-stakeholder modeling approach. In an effort to support the global vision to achieve food security and eradicate poverty, MI is currently engaged, through the Changing Course in Global Agriculture program, in supporting four pilot countries (Kenya, Senegal, Ethiopia, Swaziland) in the identification of effective and sustainable policies for the eradication of undernourishment and rural poverty. Information on the country-specific traits of the agriculture-food system is obtained through a multi-stakeholder process, which involves representatives from different ministries, university and research

institutions, local civil society organizations, and farmers' unions in the specification of the models and the scenarios. The resulting simulation models provide a highly integrated view of the sustainable food security challenge, as part of the broader food, water, energy and climate nexus. The model offers the possibility to test a broad variety of policies as well as to assess the resiliency of alternative agricultural practices to global shocks (e.g. on energy prices). The multi-stakeholder approach adopted is creating a shared perspective on the key resources that are fundamental for our food, water, energy, and climate systems, and the way they interact to provide support for human life. The identification of the underlying dominant feedback mechanisms that wire such integrated system supports the identification of leverage points for effective intervention. The shared confidence in the results produced facilitates the adoption of such results as the quantitative foundation for national strategies to achieve sustainable development and food security.

### **Applications of Land Surface Model to Assess Impacts of Climate and Land Use Change on Surface Runoff and Groundwater Recharge Systems**

Aksara Putthividh, Chulalongkorn University

Significant population increase, migration, and accelerated socioeconomic activities have intensified environmental and land use changes over the last several centuries. The climate impacts of these changes have been found in local, regional, and global trends in modern atmospheric temperature records and other relevant climatic indicators. An important human influence on atmospheric temperature trends in extensive land use/land cover change (LULCC) and its climate forcing, including water runoff, groundwater recharge, and soil loss. Land use and land cover play critical roles in land surface-atmospheric interactions and thus influence climate. Studies using both modeled and observed data have documented these impacts, it is therefore essential that we detect LULCCs accurately, at appropriate scales, and in a timely manner so as to better understand their impacts on climate and provide improved prediction of future climate as well as other subsequent hydrological processes. It has become clearer from various studies that data used in existing long-term climate assessments have undocumented biases that have not been corrected using data analysis and data adjustment techniques. The objective of this assessment is to understand how current and predicted changes in land cover and land use will alter weather, climate, and surface runoff. These interactions are necessary basis for managing and adapting to future environmental changes. The two most common spatially explicit maps of current land cover in Thailand are the 2008 and 2010 National Land Use/Land Cover Database. The purpose of this article is to identify the effect of local-scaled land use pattern on rainfall-runoff relations in Chao-Phraya river basin of Thailand using SiBUC land surface modeling technique. Using downscaled products from regional climate simulations along with local land use database yielded better simulation of rainfall-runoff relationships in Upper Chao-Phraya river basin. Spatial groundwater recharge could be estimated based on soil classification map, resulting in potential recharge zone identification for future groundwater development in the area of interest.



**Securing peace dividends through navigating a regional water, food, carbon and energy nexus in southern Africa**

Gavin Quibell, Climate Resilient Infrastructure Development Facility

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The Southern African Development Community (SADC) comprises 15 Member States, of which 12 are on mainland Africa. All or much of the territories of the mainland SADC countries lie in 15 transboundary basins which together hold more than 70% of the region's surface waters. However, these basins are characterised by widely varying water resources availability. The southern basins face physical water stress; but support the region's strongest economies. The northern basins are better watered; but water use and food production does not support strong economies in these basins. SADC as a whole is a net virtual water importer in spite of the water 'surpluses' in the northern basins. Long-term plans to ensure water security in the south have already mooted the possibility of bringing water southward, to meet the increasing water and food demands of a growing middle Class population. This is likely to raise concerns in the northern nations who envisage growing water and energy demands in their own countries, and the opportunities to grow food and generate hydropower for export. These large scale water transfers will also hold significant environmental impacts and the costs of water delivered through these mechanisms may soon be prohibitively expensive. Energy production in SADC is characterised by two inter-linked power networks, a northern hydropower dominated network, and a southern thermal dominated network. Because the stronger economies of the south exert the greatest power demands, SADC as a whole derives up to 75% of its energy needs from thermal power stations, which in turn consume 2% of the country's water. A heavy reliance on coal fired energy makes South Africa one of the world's highest per capita carbon producers relative to its GDP, while the strategic nature of power generation means thermal generation is regarded as a priority water user even in severe drought. The availability of energy is expected to be a significant driver of regional economic growth, and all the SADC States are activity pursuing increased energy production - the north through hydropower, and the south through coal fired power and exploiting shale gas reserves. Complicating dimensions lie in climate change projections which suggest that the wetter areas may get wetter, and the drier regions drier. Three of SADC's Member States are expected to be in the 10 fastest growing economies of the next decade, promoting even higher demands for water, food and energy. Yet further complicating dimensions lie in the fact that southern Africa is one of the key areas being targeted for foreign land acquisition, ultimately contributing to the export of virtual water out of the region. Many countries in SADC faced with increasing international oil prices are also increasingly pursuing biofuel production supported by irrigation. This congruence of drivers, unless carefully managed, may increase regional tensions over water in the next few decades. This paper will explore how a regional approach to navigating the water, food, carbon and energy nexus; sharing virtual water in food and energy around the region; can contribute to regional stability and can secure lasting peace dividends for SADC. The authors will show how the UKAid's Climate Resilient Infrastructure Development Facility (CRIDF) - being

implemented by an Adam Smith International lead consortium - will encourage regional strategic approaches to navigating the nexus through infrastructure projects specifically aimed at water, food and energy production. This will help establish a platform through which the Facility can start helping the countries see beyond sovereign water, food and energy production towards regional security across the nexus.

### **The Benefits of Farm Animal Welfare for Sustainable Food Production**

Barbara Romanowicz, World Society for the Protection of Animals

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Humane and sustainable livestock production is integral to achieving socially and environmentally responsible outcomes for the future of food production, poverty eradication and sustainable development. The UN Rio 20 Conference in June 2012 formally recognised the importance of promoting sustainable livestock production and enhancing livestock health. This paper will outline the contribution animal welfare makes to sustainable productive livestock production now and in the future. Original research commissioned for WSPA reveals the extent to which livestock contribute to food security and livelihoods and how improvements in animal welfare can benefit productivity. In contrast, there are significant risks posed by unsustainable production methods and consumption patterns of livestock products, for both the global environment and societies. Increasing animal feed demand has diverted grain and protein from human needs, influencing food price volatility. Increasing demand for animal feed potentially decreases self sufficiency of newly emerging and developing countries, particularly in Asia. Industrial style livestock production also places a significantly larger burden globally on 'blue' water resources, which would otherwise be available for human use. Industrial scale intensification also brings a range of animal welfare problems: systems that prevent natural animal behaviours, lead to animal health problems and disease. Solutions are needed now to ensure the ability of livestock production to meet our needs for food, income and social safety. Humane sustainable agriculture can deliver effective solutions: efficient food production, resilient farming systems, nurturing livelihoods and managing environmental pollution. Evidence and real examples presented here will show that ensuring the welfare and responsible use of animals can be a highly effective tool to achieve sustainable development, safeguard food and water security, deliver poverty alleviation, enhance nutritional security and human well-being and also produce significant positive outcomes in terms of major global concerns of climate change and public health.

**Water for Food and Energy in the Water Scarce Western U.S.**

Benjamin Ruddell, Arizona State University

Water is an important constraint on energy and food production in dry regions of the world. The Western U.S. exemplifies a highly developed water-constrained system, and is therefore an important illustration of the tradeoffs inherent in water use. The Western U.S. is one of the most productive regional economies in the world. Despite water limitations, the Western U.S. is still a major producer and exporter of many types of energy and agricultural products. Some of these products are more water-intensive and less valuable than others, and are therefore the most likely to be targeted by water reallocation policies. However, economic trade is a powerful driver of water use, and the resulting patterns defy principles of water efficiency.

**Exploring City CLEWs- Climate, Land, Energy and Water strategies**

Rebecka Segerstroem, KTH Royal Institute of Technology

Additional Authors: Brian Deal

As global populations increasingly urbanize, so does the demand for reliable water, energy and food systems. Approaches to the delivery of these systems vary with economic and geographic conditions, political context, and the availability of technology. As a result there is an uneven distribution of services, especially when considered from an economic, social or environmental sustainability perspective. This paper, under the working title City CLEWs (short for Climate, Land, Energy and Water strategies) describes a framework for understanding how cities manage their physical and natural resources ( even though they might have been transformed several times before reaching the city) in order to deliver critical services that contribute directly to the wellbeing and prosperity of their citizens. We argue that a specific focus (zooming in) on these resource-to-service flows using a comparative analytical approach can help provide insights on urban sustainability, including efficiency, vulnerability, equity and policy formation. Using a comparative approach, we can identify differences in resource to service flows to answer several important questions: a) How do different cities supply critical services? B) Are these approaches contributing to the sustainability of their communities? C) If so, can these approaches be translated into different cultural contexts? The evaluation of these flows might be made in terms of 'quality of life' measures - GDP/capita, human development index, or simply by looking at what services the population of each city has access to. We argue that a comparative approach can go further in identifying links between critical systems and their resulting service provisions in ways that would not be possible looking at a single city's resource-to-service structure. The first phase of this work, involves building the methodological framework to quantitatively analyse urban resource flows. To do this, we explore the applicability of two open-source modelling tools to analyse

the interlinked resource-to-service systems in simplistic models of Stockholm and Chicago: the OSeMOSYS energy modelling tool and the LEAM dynamic spatial urban transformation model. OSeMOSYS, the Open Source Energy Modelling System, is a fully-fledged systems optimization model for long-term energy (and other resources) planning, recently developed by KTH and partners (see Howells et al (2011) "OSeMOSYS: the open source energy modelling system: an introduction to its ethos, structure and development", *Energy Policy*, 39: 5850-5870). It is structured in blocks of functionality, giving it a flexible model structure that is possible to customize to the system studied. The Land-Use Evolution and impact Assessment Model (LEAM), developed at University of Illinois, Urbana Champaign, is used to simulate land-use change across space and time. Drivers that contribute to land-use change are assessed in contextual sub-models that run simultaneously in each grid cell of raster based GIS map(s). Together they produce landscape simulation scenarios that can be used to identify environmental, economic and social impacts of different types of land use change. It has among other things been used to test the ecological implications of land use decisions over various geographies (see among many others: Deal et al. (2009) "Sustainability and urban dynamics: Assessing future impacts on ecosystem services". *Sustainability*, 1: 346-362). The development of a City CLEWs modelling framework builds on successful exploration of the CLEWs framework on national, transnational and global scale (see e.g. Howells et al. (2013), "Integrated analysis of climate change, land-use, energy and water strategies", *Nature Climate Change*, 2013 - vol. 3, and UNDESA (2013) "Global Sustainable Development Report - Executive Summary". New York: September 2013) coupled with expertise on sustainable urban planning. Insights from a previous study on modelling the water-energy nexus in New York City will also be used to inform this work (see R. Segerstrom (2011) "Building a Water-Energy Nexus Modelling Tool for New York City: Development of a NYC WaterMARKAL model", MSc. Thesis Uppsala University). The work is at present leading up to a first collaborative scientific paper by KTH-dESA analysts and senior researchers from the Department of Urban and Regional Studies at University of Illinois, as part of the KTH-UIUC Comparative Cities project.

### **From Waste to Worth: How a Pig Farm Generates Environmental Revenue**

William "Gus" Simmons, Cavanaugh & Associates, P.A.

The innovative Swine Waste-to-Energy project at Loyd Ray Farms, near Yadkinville, North Carolina, is N.C.'s first project to generate and transfer renewable energy credits (RECs) from a swine facility in accordance with NC's Renewable Energy Portfolio Standard.

The project began as the utility companies of North Carolina began to evaluate the potential of making renewable energy sources. Duke Energy approached the Nicholas Institute for Environmental Policy Solutions at Duke University to aid in their assessment, and help them determine how to go about transforming pig waste into power.

The team developed a model for anaerobically digesting swine waste to create a methane-rich biogas, that could fuel electricity generators, and agreed that they should also include goals of improving the environmental performance of swine farms, which included the substantial reduction or elimination of the emission of odors, ammonia and disease transmitting vectors, as well as the elimination of the potential for run-off of ground and surface waters by nutrients, pathogens, and heavy metals. The innovative system demonstrates that electricity can be generated from swine waste, and the odors and emissions can be treated while at the same time generating revenue to run the farm and to repay the capital cost for construction.

### **The Water-Energy-Food-Climate Nexus and National Security**

Monica Smith, U.S. Department of Defense

In recent years, there has been a tremendous increase in academic reporting of links between climate stress and armed political conflict. A failure to integrate the systems of the Water-Energy-Food-Climate Nexus leads to unintended consequences, often causing shifts in livelihoods and contribute to civil unrest. Institutions that manage nexus systems as separate sectors fail to coordinate or recognize the competing relationships among systems. To promote political stability or anticipate conflict in a country of interest in light of new infrastructure, demographic changes or climate change, one must factor in all resource aspects of the nexus because they are so intertwined. In our prototype of the Helmand River Basin Geonarrative, we illustrate how interactive web-based visualization allows you to qualitatively integrate different types of information that are typically stovepiped among analytical units. This prototype geonarrative demonstrates the shift of analysis from a writer-driven to a user-driven design and how information can be organized spatially to explore interdependencies of a system in a map-based context.

### **Social Entrepreneurship and the Emerging Nutrition Economy**

David Strelneck, Ashoka Innovators for the Public

Over the past four years, Ashoka has searched for patterns amongst the real-world innovations of system-changing social entrepreneurs who focus on agriculture worldwide. These are pioneers of new economic, social and technological ideas who have been elected as Ashoka Fellows, which now number over 3,000 in 71 countries. These leading social entrepreneurs tend to see forces that are five to ten years ahead of mainstream society, and we believe that their innovations offer practical insight into emerging shifts, trends and opportunities in the world. This effort has led us to identify a striking pattern and, we believe, a powerful framework for action. We call it nominally "the nutrition economy." This view, informed by the examples and actions of social entrepreneurs across Africa, India, Europe and elsewhere, reflects two core ideas. Importantly, these apply whether you operate in the healthcare, food, agricultural or environmental sectors: \* First, that a focus on achieving wellness and vitality leads

to different assessments, success metrics, and innovations than does a more traditional focus on treating sickness or degradation. Such a focus orients fundamentally around outcomes or results, rather than discrete treatments and inputs. \* Second, that considering and measuring the full "nutrient spectrum" - which is not done in any of these sectors today - provides a consistent, practical and powerful unit for analysis, communication and transaction, both within and across those traditional sectors. In short, full nutrition represents an actionable nexus between environment, agriculture, food and healthcare. It offers practical opportunity for wellness-focused food consumers and healthcare systems, motivated by and armed with new information, to drive demand for regenerative agricultural and environmental systems that supply the nourishment to begin with. In this sense, the "nutrition economy" not only nourishes plants, animals and people, but also triggers wide ranging ancillary benefits within each sector. For example, fully nourished (rather than malnourished) soils which farmers and businesses must steward to meet demand for measurably-nourishing foods also stimulate regenerative ecological benefits associated with living soils: improved watersheds, reduced topsoil erosion, pollution filtering, carbon sequestration, improved ecological and economic resilience to weather extremes, etc. Similarly, on the direct human side we see and foresee improvements in workforce productivity, educational performance by children in schools, infant-maternal health, and more. Finally, key aspects of this framework must be understood: Orienting around the "spectrum" rather than individual nutrients reflects actual bioavailability rather than just contents of diets we feed ourselves or our crops. The cross sectoral aspect establishes the value chain underpinning this economy, linking supply and demand. And, understanding, measuring and transacting in full nutrition is becoming possible because of the global information revolution and the miniaturization of diagnostic technology (specifically including mini-mass spectrometry and smart mobile phones linked to large data aggregation). We're happy to present examples of the social entrepreneurs along this emerging value chain; the most important points of action we see for connecting larger systems to accelerate and spread these approaches; and additional design principles reflected in the economic and social innovations that form this pattern.

### **Implications of Climate Change for Euphrates-Tigris Transboundary Basin: Intricate Nexuses between Water, Security and Food**

Vakur Sumer, Selcuk University/ UNC's Global Research Institute

This paper aims to analyze water related implications of climate change in Euphrates-Tigris (ET) transboundary river basin, and explore the complicated web of relations between water, security and food in the region. The Mediterranean basin and its surrounding area, which includes Mesopotamia is regarded as among the most climate-vulnerable regions in the world. Climate change is already underway in the ET region. The increasing impacts of climate change in the Euphrates Tigris region have been experienced by a number of indications Voss et al. (2013) analyzed the changes in overall freshwater storage in the Euphrates-Tigris basin from January 2003 to December 2009. Their study indicated alarming rate of decrease in total water storage of approximately  $-27.2_{-0.6}$  mm yr<sup>-1</sup>

equivalent water height, equal to a volume of 143.6 km<sup>3</sup> during the course of the study period. Indeed, a decreasing trend in Lower Euphrates streamflows based on historical flow data analysis has already been demonstrated (Yilmaz and Imteaz 2011, 1277). Moreover, despite the decrease in overall precipitation, flood intensity and frequency has a tendency to rise (IPCC, 2007) The drought in Iraq in 2008, a case in point, was one of the harshest ones in the country's history which forced the country to enter into new negotiations which then culminated in signing of a memorandum of understanding in September, 2009. Climate change induced impact was particularly devastating in Syria, as al-Tamimi and Svadkovsky (2012) note "agriculture remains a major part of the economy and the lifestyle of a large section of the population, some 20% of Syria's GDP being generated by this sector". It was reported that "aggravation of water scarcity led to the abandonment of around 160 villages in northern Syria in the period 2007-2008. In eastern Syria, the Inezi tribe saw some 85% of its livestock killed between 2005 and 2010 because of prolonged drought. In 2010 the United Nations estimated that more than a million people have left the northeast of the country" (Al-Tamimi and Svadkovsky 2012). This in turn create not only intra-state but also inter-state security challenges like "climate change migration". Thus, any cooperation attempt in the Euphrates-Tigris basin should aim at improving the water use in agriculture. Because, the greatest consumer of water, by far, in the Middle East is irrigation/agriculture. As pointed out by Shetty (2006), countries in the region now face with "increasing pressure to allocate water away from agricultural to industrial and municipal uses, as well as to increase water efficiency within the agricultural sector". On the other hand, rapid population increases put the region in a pressing dilemma: improving agricultural water use appears to be difficult with the continuing trends of population increases in the basin. Recent climatic models for eastern Mediterranean and Turkey predict a significant reduction in precipitation (Gao and Giorgi 2008) that would require additional water withdrawals from the Tigris and Euphrates Rivers to meet agricultural demand throughout the basin.

### **Water policy and farms' livelihoods in South Africa**

Djiby Racine Thiam, University of Bonn

1. Overview More than a decade after the reform of the water sector, water allocation in South Africa is still undergoing many changes to integrate additional aspects such as equity in distribution among the different users, control of the resource's sustainability and integration of local stakeholders into the water management practices. More water for food production and industry development has stressed many catchments and deteriorated water quality of many basins in the country (Walter et al, 2011; Hassan and Thurlow, 2011; Zhu and Ringler, 2012). In the agricultural sector, representing the major user of water in the country, water allocation for irrigation was tied to land ownership excluding quasi-implicitly the historical disadvantaged individuals on access to water rights. This paper uses one of the most water stressed catchment in the country (the Olifants river basin) to assess the impacts of water market and a policy of compulsory licensing on farms' livelihoods. Compulsory licensing is a policy introduced in the National Water Act (1998) to promote a re-allocation of water resources in water stressed catchments in South Africa. This policy is argued to promoting (a) the rise of emerging farms

and (2) a re-balance of past discriminatory riparian-based water allocation schemes. Water market is a mechanism promoting a voluntary transfer of water-use rights, for a financial compensation. In the agricultural sector water market assumes that farms holding licenses that are not used after a completion of irrigation schemes (latent license holders) sale such licenses to the ones that still need additional water (deficit license holders) to complement their irrigation schemes.

2. Methodology We provide an integrated optimization modeling approach combining water and agricultural modules. The model maximizes net farms' profits and takes into account the characteristics of the agricultural sector in the region by classifying farmers between large-scale (LSFs) and small-scale (EFs) groups, according to their land acreage, irrigation efficiency and past historical heritage. Compulsory licensing is analyzed through curtailment of water-use rights from large-scale to emerging farmers. Water market is investigated in providing conditions under which farms trade water to complete their irrigation schemes

3. Results The results show that, though compulsory licensing might encourage a rise of emerging farmers and a re-balance of past riparian-based water allocation schemes, care should be given to the scope of that curtailment rate in order to match equity measures with efficiency objectives. Indeed the losses associated with water curtailment for LSFs are not entirely captured by the EFs. Therefore, beyond water policy, there are other factors, which also influence farms' profits and water use efficiency. The results also demonstrate that water market provides a good option to increase water use efficiency. The introduction of water market induces LSFs with good water storage facilities a possibility to trade their remaining water-use rights and to EFs an alternative to diversifying their water supply sources, once they face shortfalls in amount of water allocated.

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### **The Nexus in Caribbean SIDS: Central To Sustainability Water Energy Food Climate- Policy and Possibility**

Liz Thompson

On the nexus issues of water climate food and energy, Small Island Developing States stand on the front line of assault. Some are slipping over the edge, and will need life-lines if they are to be pulled back on to the path of sustainable development. This view of isles of crisis is incompatible with the fairy tale we enjoy of SIDS being perfect idyllic settings where all is right in the world and gentle waves lap white sand beaches. The reality is that the scale, frequency, enormity and degree of challenge presented by environmental issues in SIDS is without parallel and warrants the attention of the international community, especially with the upcoming SIDS conference in Samoa September 1st to 4th, 2014. Even in middle income SIDS which have addressed many development issues such as access to health and education, pushed back on the spread of HIV/AIDS, achieved some of the MDGs and built relatively good



infrastructure, there is now such a severe threat from environmental sources, particularly on the nexus issues that these countries have to rethink their approaches to development, especially in the post-crisis period following the global free fall of food, fuel and finance which severely impacted on SIDS, and when coupled with their high and unserviceable debt ratios, exacerbated their development challenges and threatened their development prospects. At the United Nations Conference on Small Island Developing States held in Barbados in 1994, where the Barbados Programme of Action (BPOA) on SIDS was birthed, identified SIDS as being peculiarly vulnerable to external environmental and economic shocks, having limited capacity to respond to external threats, too small to generate economies of scope and scale, having limited capacity for trade and economic expansion as a result of limited natural resource bases and small population size. At the Conference the global community, led by SIDS recognised these states as having 14 priority areas which include 3 of the nexus issues climate, water and energy. -climate change and sea- level rise -natural and environmental disasters -management of wastes -coastal and marine resources -freshwater resources -land resources -energy resources -tourism resources - biodiversity resources -national institutions and administrative capacity -regional institutions and technical cooperation -transport and communication -science and technology Any reversal of negatives trends in SIDS will require policy and programmatic attention to the nexus issues and ensuring that sustainable development is embedded as a core ethic of how SIDS nationals live and do business. Socio-economic nature of the food, water, energy, climate nexus became apparent when Sandy, a Category 3 hurricane hit New York City, which has considerably more financial resources than any microstate many of which are hit by category 5 hurricanes and sometimes more than one cyclone or hurricane in a single season. More than ever before the nexus issues become a point of contact for government business and society. They are the axles around which people, profit, planet and prosperity revolve. What would the transition to a green economy in the context of the Caribbean SIDS look like, how would it be achieved and how does one locate nexus issues in the context of a green economy in SIDS?

### **Engaging the Public in Improved Water Management through Community-based Urban Agriculture**

Bobby Tucker, Tetra Tech

As relationships between water and energy become more apparent, it is important to maintain discussion of the third major element in our global resource nexus ?o food. The industrialized production, distribution, and consumption of the U.S. food supply is a significant contributor to increased water/energy demand and associated environmental impacts. At the same time, experienced watershed managers are arriving at the conclusion that watershed goals will not be met without the full engagement of the public. In an era of budget cuts, growing poverty, and increasingly unequal wealth distributions in the U.S., it is becoming clear that full public engagement requires the implementation of strategies that directly serve the basic needs of the citizenry. The time is right to take the implementation of LID and green infrastructure practices to the next step to make our urban landscapes more productive and multi-functional in support of food production and a community's basic needs. This presentation will use several case studies to highlight how urban agriculture can be a solution for

efficiently achieving a broad range of societal goals, including water resource management, economic and community revitalization, public health improvement, and carbon reductions, to name a few. In addition, it will illustrate how intelligent and thoughtful land use planning can help establish a system of beneficial relationships within our built environment, simultaneously making our societies more productive while minimizing energy inputs and waste outputs.

**Energy-Water Nexus: Risks and Opportunities for Low Carbon Energy Technologies**

Marilyn Waite, AREVA Corporate Research & Development

Water is growing in importance for assessing the physical, economic and environmental viability of energy projects. The increase of water demand and energy demand are coupled; both increase with increasing population and economic growth. However, increasing water stress is bringing risks to the current and future supply of both water and energy. The energy-water interdependency also presents particular challenges for the transition to a low-carbon economy. It is important for industries working in the water and energy sectors to be aware of and act to abate the risks (and take advantage of the opportunities) that this nexus brings. This presentation will describe the role of water in energy processes, focusing on the risks and opportunities for low carbon energy (nuclear, solar, wind, and biomass).

**The Food-Water-Energy Nexus in China: Security Implications**

Elizabeth Wishnick, Montclair State University

In a globalized world, in which China's economy plays a central role, high-speed economic growth requiring vast supplies of food, energy, and water resources has an impact far beyond Chinese borders. U.S. and European policymakers and analysts speaking at the World Economic Forum in 2011 pointed to the interconnections among them—known as the food, water and energy nexus—and their likely global impact in coming decades. This paper examines the food-energy-water nexus in China and its implications for global food markets and China's increasing interest in access to "virtual water" through land leasing arrangements in other countries. A large proportion of China's energy comes from coal, which requires considerable amounts of water in the mining process. Moreover, China is a country with severe water insecurity, especially in highly populated northeastern areas, which are also the country's breadbasket. With increasing water demands from the conventional energy sector, China has been increasingly interested in finding new sources of "virtual water" and acquiring land in other countries to grow crops used in biofuels as well as needed foodstuffs. The food-energy-water nexus also leads China to rely increasingly on imported food, with important implications for food markets.

## **Corporate Water Stewardship**

Lisa Wojnarowski, Downe, The Nature Conservancy/ Alliance for Water Stewardship

Additional Authors: Dale Phenicie; Emilio Tenuta

Corporate water stewardship represents a unique opportunity for companies to improve the efficiency and impacts of their internal operations and in their supply chain, while also working towards the sustainable management of shared water resources through collaboration with others. Water links with other sustainability challenges, including food security, energy, and climate change; and requires a shared platform for addressing common concerns. A water stewardship approach, such as that outlined in the Alliance for Water Stewardship's International Water Stewardship Standard, provides a framework for companies to make a leadership commitment, assess their water-related risks and opportunities, develop a plan to minimize risks and maximize opportunities, implement the plan, assess performance, and communicate and disclose information. Although these efforts address internal management, the stewardship approach also calls for companies to support the sustainable management of water in the watersheds they operate in by collaborating and engaging with others. This platform for open dialogue and shared responses creates enabling conditions for local actors to begin to discuss shared challenges and exchange expertise related to water, food, and energy concerns. Thusly, water stewardship can drive the innovation needed to address nexus challenges through collaboration. Although the AWS Standard is at first glance a water-specific approach, it is designed to exist within a broader system that engages all sectors in driving consensus-based responses to shared water risks. This cross-sectoral approach is not limited to those who directly use a lot of water, but includes all who have an interest in promoting healthy watersheds. In this way, by focusing on collective engagement on water, the range of perspectives needed to identify cross-sectoral solutions is hard-wired into the AWS system. As a multi-stakeholder process, the AWS system helps companies better understand the spectrum of sustainability challenges they face and establishes enabling conditions to begin to respond through collective action. The AWS system also incentivizes action by recognizing and rewarding performance and behavior. The AWS Standard has been applied in a number of field applications, with tangible lessons learned. Results from applying the Standard to agriculture (in Africa and Latin America) and energy production (in North America) are of particular interest in the nexus context. Highlights from each of these areas, as well as their applicability in other contexts, will be shared with session participants. As a cross-cutting issue, water cannot be viewed in isolation. However, a water stewardship approach, such as the Alliance for Water Stewardship's International Water Stewardship Standard, can provide a framework for multi-dimensional dialogue across stakeholders and establish a foundation towards collective action to address shared resource risks and opportunities.

### **Impacts of Climate Change on the Water-Energy-Food Nexus in the Indus Basin of Pakistan**

Yi-Chen Yang, University of Massachusetts-Amherst

Additional Authors: Hassaan Khan; Claudia Ringler; Tingju Zhu

The Indus River Basin forms the backbone of Pakistan's economy, providing crucial water and food security to the country. In addition, over a third of Pakistan's national energy supply is generated by the basin's water resources. Our previous results suggest that under the current system no significant tradeoffs are observed between hydropower generation and crop production due to the inflexibility in water allocation, relatively fixed reservoir operational rules and low electricity prices. However, tradeoffs across, water, energy and food are set to change as a result of the development of new hydropower infrastructures that are pushed by the recently elected new Government of Pakistan as well as a result of growing climate change impacts. This paper will address these concerns. The study uses the Indus Basin Model Revised-Multi-Year (IBMR-MY), a hydro-agro-economic model, to evaluate the changing water-energy-food relationships in Pakistan under uncertain climate risks. The latest climate change projection: the fifth phase of the Coupled Model Intercomparison Project (CMIP 5) will be used to alter streamflow, temperature and precipitation in the model and results will focus on the tradeoffs between water use for hydropower generation and for crop production. New hydropower infrastructure, such as the recently raised Mangla Dam, the soon to be finished "run-of-river" hydropower project Neelum-Jhelum and the planned Diamer-Bhasha dam will be incorporated into the modeling structure. This study will thus contribute important insights for water, energy and agricultural sector planning in Pakistan.

### **Natural Capital Evaluation as a Nexus of Water, Energy, and Climate: Best Practice in the Financial Sector in Japan**

Masaru Yarime, University of Tokyo

Natural capital consists of the elements of nature that produce value or benefits to people directly and indirectly as well as natural processes and functions that underpin their operation. Among the elements included in natural capital would be as follows: water (surface and underground); carbon (stocks both below and above ground); energy, including coal, oil, natural gas, biomass, and renewable energy sources such as wind power and hydro-electric dams; minerals, such as iron, copper, phosphorus; air quality, with impacts on human health as well as habitats and wild species; wild foods and fisheries, such as fish stocks and other edible species; soil, with its role in primary production, decomposition, nutrient cycling, bioremediation and other processes; agriculture, aquaculture, and forestry, including timber, fuel, fiber, farmed fish, seaweed and kelp; and wild species and habitats. The quality of natural capital, such as configuration, distribution and accessibility, is just as important as its quantity. The use and exploitation of natural capital supports the development of economies over time and underpin

everything we collectively produce and consume. Corporate activities, including the supply of raw materials, are also relying significantly upon natural capital, as these natural elements contribute to economic prosperity and wellbeing. Natural capital, however, is limited in quantity and quality and threatened by excessive exploitation in the context of the rapid economic expansion and explosive population growth particularly in developing countries. Governments, local associations and corporations have started to make serious efforts to recognize the economic value of natural capital. It is increasingly becoming necessary for private and public enterprises to understand how much they depend on various types of natural capital through the entire supply chain ranging from suppliers to consumers. That would be important not only for the purpose of environmental preservation, but also for the design and implementation of corporate strategies for risk management in the procurement and use of raw materials. A private bank in Japan has recently started to provide the service of environmental rating loans with the use of natural capital evaluation. The decision on finance is influenced by the assessment of the borrower's activities in terms of contribution to preserving natural capital. This practice would be one of the first cases across the globe in which the evaluation of natural capital is actually adopted as a crucial criteria in making decisions on providing finance in the banking sector. The evaluation result includes how much the activities of the company affected the fundamental elements of natural capital, such as water, air, and soil in the upstream of the supply chain, in addition to the data on the amount of water consumption, occupation of land surfaces, and greenhouse gas emissions, classified by region, country, and product procured. Together with the result of the evaluation of natural capital preservation, the company borrowing money from the bank is also provided with advises and recommendation on how to address the various types of risk associated with the corporate activities' impacts on natural capital. These data will be very useful for complying with other requirements to disclose information, for example, Scope 3 in the Carbon Disclosure project. It is very difficult, however, for private companies to make calculations for creating such data. A critical challenge is how to develop an appropriate model with accurate industry-related charts and trade statistics so that reliable estimates can be made for the impacts on natural capital in the upstream of the supply chain. At this moment there has not been a consensus widely achieved with regard to which methodology should be adopted, considering the diversity of industrial sectors and geographical locations. It is also important to establish a system to guarantee the reliability of the data used for the evaluation of natural capital so that comparisons can be made with other companies with diverse backgrounds. The range and accuracy of data and information in the upstream of the supply chain required for calculating the impacts of the corporate activities on natural capital also needs to be clarified. In this presentation these challenges as well as potentials of the best practice of utilizing the evaluation of natural capital in the financial sector in Japan are discussed, with implications for corporate strategy, public policy, and institutional design.

**Understanding the Water-Energy Nexus in the Caribbean: The Importance of Sociocultural Context and Political Economy to Wastewater Management**

Rebecca Zarger, University of South Florida

Additional Authors: E. Christian Wells; Linda Whiteford

In this presentation, we describe the ways sociocultural context and changing political economies shape the provision of wastewater management strategies in tourism-focused economies in the Caribbean. We describe the critical role that integrated sociocultural and bioengineering research can play in assessing community interest and capacity to reclaim and use water, nutrients, and energy from novel wastewater systems that are being implemented throughout the Caribbean. We describe ongoing research in Yucatán, Mexico, Belize, and St. Thomas, USVI that aims to examine the links between extensive tourism development, water and wastewater management, and local livelihoods. We focus on NSF-PIRE-funded research with anthropologists, environmental engineers, and marine scientists on the Placencia Peninsula of Belize, which has experienced dramatic growth in the tourism industry, driving concerns about increasing demands for water, energy, and human waste removal. Compounding the situation, increasing seasonal flows of foreign and domestic tourists along with recent discussions of implementing mass tourism through cruise ship ports has exacerbated concerns for future energy consumption in the region. To address the needs for water/wastewater management in the area, the Government of Belize recently received a \$10 million loan from the Caribbean Regional Fund for Wastewater Management to design and install a wastewater collection, treatment, and disposal facility. Our research explores the ways and extent to which local village councils, environmental NGOs, tourism organizations, lodge owners, and other community stakeholders are involved in this process as well as their beliefs about potential costs and benefits to the economy, environment, and local autonomy to guide future tourism development. We consider role of scale in determining potential outcomes for stakeholders in development of new wastewater systems, in particular the negotiations between local, regional, and national actors in project feasibility studies and future implementation. The greater goal of our research is to better understand how more sustainable management of wastewater—including the recovery of energy and nutrients—enables and constrains relationships between tourism, ecosystem health, local livelihoods, and wellbeing.

# Poster Presentations

**Responding to Climate Change Impact: Water, Energy, and food Nexus in the Arab Cities**

Maha Al-Zu'bi, University of Calgary

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The Arab Region is challenged by population growth, urbanization, economic growth, availability and consumption of natural resources, and water scarcity-related problems and impact resulting from climate change. This research examines the existing interactions between Water, Energy, and Food (WEF) from a water scarcity perspective, with both energy and food considered as users, at the municipal level. Previous research has discussed these elements and related governance issues in global and national contexts while neglecting the municipal level - the most appropriate policy and political jurisdiction for bringing about necessary demand reduction, where the majority of the population is living; and most of the WEF are consumed. For instance, policy debate and governance in the Arab countries are centralized with limited integration and interactions between the WEF sectors. The goal of this research is to develop a WEF Nexus Municipal Policy Framework to respond to climate change impact in the Arab cities. This research charts three phases: (i) A comparative analysis between the Arab Region's four sub-groups namely: Gulf Region, the Mashreq, the Maghreb and the Least Developed Countries help explore, identify, and describe similarities, differences, challenges, and opportunities in terms of the existing governance and WEF national policies; (ii) Develop WEF Nexus Municipal Policy Framework based on reviewing the literature and precedents in the area; and (iii) From the Mashreq sub-group, Amman City in Jordan has been selected as a case study to perform a city-level quantitative and qualitative assessment. Various public participatory approaches have been considered to validate the WEF Nexus Municipal Policy Framework. The preliminary findings of this study provide: a comprehensive perspective on WEF nexus challenges and opportunities at the municipal level; research foundation to enhance city-level engagement in national policy dialogue, and facilitate transition to a Green Economy, and consequently contribute to sustainable development.

**Nexus between water shortages with climate change and food security in coastal Bangladesh**

Mehdi Azam

The country of Bangladesh is highly vulnerable to the impacts of climate change due to its geographical location, extreme poverty and high economic dependence on climate sensitive sectors like agriculture, food and fisheries. To make things worse, irregular weather patterns in recent years have also exacerbated the impacts of climate change, particularly in Bangladesh's vulnerable south-western coastal region. This paper investigates long-term impact of water scarcity in this regions has an adverse implications on food security and intensifying climate change impact. Analysis reveals that water availability in this region mostly depends on wish and demands of upstream countries mainly India and China which has several implications such as silting up river beds, inland salinity ingression. These



impacts have been fueled up by the mismanagement of water in the coastal polders and intensive shrimp farming. That's leads to lack of water availability in dry season causing drought and excess water availability in rainy season causing serious flooding. Agricultural production is being serious hampered in the recent years leading to food insecurity in this region. Moreover, drinking water scarcity is common in all seasons. It also examines the climate change adaptation strategies undertaken at the grass-roots level, in order to propose improved strategies for mainstreaming climate change adaptation and mitigation. Although some strategies to mitigate the impacts of climate change have already been implemented, there seems to be a lack of adoption of these initiatives at the local level. This paper suggest an integrated approach to introduce technological incorporation in water supply management and regional cooperation in major water development projects to minimize climate change impacts and ensuring food security in this region. This paper finally concludes that less overlapping and more effective integrated actions between communities, civil society organisations, NGOs and various local government departments are needed in order to build a climate change resilient community.

#### **Working of the Hill Women: A Case Study of the Hill Regions of India**

Hema Bhatt, University of Agri & Technology

Additional Authors: Promila Sharma

Three weeks without food, three days without water, and three minutes without air - that is the rule of thumb for human survival. India, being a vast subcontinent, has an extensive area of hilly terrain (Sundaram and Palanidurai, 1990). About 70% of hills population is engaged in agriculture (WMD, 2010). Women's workload in agricultural societies often exceeds that of men (Mpetsheni, 2001), and collecting food, fuel and fodder are the most time-consuming activities of the hill women. The present study was undertaken to investigate water, fuel and fodder access to the hill women, also to know the time spent for their collection. Data was collected purposively from the Uttarakhand state for the present investigation. Purposive sampling was adopted which involves deliberate selection of particular unit of the universe on convenience basis. It was reported that the never ending work starts early in the morning by about 5 am and stops only by about 10 pm managing all the household, farm, livestock, and other productive activities. Their daily lives include heavy tasks of cultivation, water collection, fuel and fodder collection by trudging along the mountainous roads and hilly slopes for as much as 10 to 15 km a day, in search of necessities. Because of depleting water sources and receding forests, multiple trips are now made each day to obtain sufficient water for the household, thereby increasing caloric expenditures at a time when health is likely already compromised. With the changing environment, unpredictable weather changes have caused mountain people, especially the women, to become the worst victims of global warming, due to lack of preparedness and vulnerability. The many hours that women in hills spend doing routine tasks such as fetching water, fodder and firewood grow even longer with the changes in the climate and forest degradation.

**The Challenges of Urbanisation: The Need for Integration in Community Resilience to Disasters and Disease**

Naira Costa Chaves, WSPA

Additional Authors: Nicole Fassina; Frances Abson

By 2050, over 70% of the world's population will live in cities (WHO, 2013). Increasing urbanisation brings with it many challenges for human and animal health, including the threat of disease. The trend for animal owners to bring their animals with them into urban and peri-urban environments calls for greater pooling of government resources pre- and post-disaster (IFRC, 2010). While animal-based livelihood practices have largely adapted to the urban context, development programming has not always responded by considering how animals should be incorporated into emergency responses and capacity building. Avoidable economic and human health disease burdens arise because of a lack of integrated healthcare and emergency response (IFRC, 2010). WSPA works in partnership with local and national governments, NGOs and IGOs to support the inclusion and roll out of various cross-cutting solutions which work towards building stronger, more resilient communities. WSPA has developed practical tailored solutions: from proving that a humane response to canine rabies works best for animals and people, to preparing communities for disaster so that both human and animal welfare is protected. Tangible examples of our work demonstrate that cost-effective solutions exist that facilitate saving the lives of animals and people as part of an integrated approach. In the context of the challenges posed by disease in an urbanised setting, on-going holistic efforts will be required to make sure the needs of the community are met in a rapidly-changing environment.

**GIS- based framework to integrate spatial data, water supply modeling, billing software and remote sensing data to reduce NRW in water supply schemes**

Jayantha Ediriweera, Bogan Shire Council

Non-Revenue Water (NRW) is an important issue facing water utilities considering it has an estimated value of over \$18 billion per year worldwide. NRW is the difference between the volume of water supplied to the system and the volume of water that is billed to the customers. The ability of controlling NRW to ensure efficient use of water resources is critically important since the legitimate water consumption is expected to increase 40% by 2025. Traditional solutions that are intended to help water utilities effectively manage NRW levels are limited and often expensive and difficult to implement. Therefore this paper presents how GIS data platform can effectively use to develop a management tool to reduce and monitor the NRW in water supply systems. The all NRW contributory factors such as system pressures, ground elevations, water consumption and demand patterns, leaks and brakes, aging of infrastructure could be monitored in this single GIS based platform as a management tool. This GIS model can play a vital role as a tool of transformation of information, communication and decision

making on water supply planning, designing and modeling. This pilot study was conducted in one of the highly urbanized city, Colombo in Sri Lanka. Initially, Digital Elevation Model (DEM) was prepared for the pilot project area since ground elevation is the most predominant factor for planning, designing, operation and maintenance of water schemes. It gives the spot elevations in the pilot area. Subsequently, satellite image of the pilot area was overlaid on DEM to acquire the spot elevations in required locations. At the same time, GIS could provide three dimensional (3D) views of the area for better understanding of the overall condition of study area. Especially, this kind of 3D view with the spot elevations helps implement effective pressure management program to reduce NRW, both designing and maintenance activities of water supply systems. This model has facility to integrate the WaterCad hydraulic model, to visualize the encapsulated knowledge of pressure, demand and infrastructure data in numerical models. Additionally, demand surveys, zoning and pressures management could more realistically be done with the help of this GIS based model. As the next step, the billing account numbers and GPS coordinates were assigned to each building polygon which represents the consumer premises in digitized building shape file. Having assigned the spatial billing references of consumer premises, the ORACLE billing data base was linked to this GIS model. Then, this data base could be used to analyze the billing, collection, and metering and consumer data with spatial references. Furthermore, entire technical and nontechnical data, such as pipelines, roads, road names, valves, water demands, pressures, etc could be overlaid and integrated to this model. This model could be used as a modern management tool to monitor and control the NRW and increase the water efficiency to serve the future water demand and also could be used as asset management tool to initiate operational, maintenance, capital renewal and new capital strategies in water utilities.

**A review of coastal and water resource policies in Japan: a nexus between water and food**

Aiko Endo, Research Institute for Humanity and Nature

Additional Authors: Pedcris M. Orencio; Makoto Taniguchi

In Japan, multisectoral coordinating mechanisms, and a comprehensive and integrated approach for ocean governance was needed. In 2007, the Basic Act on Ocean Policy was enacted consisting of 6 basic principles and 12 basic policy measures. The Development of an Integrated Coastal Management, or ICM is one of the basic policy measures. This Act was the first to formally recognize the need for implementation of ICM. In the subsequent year, the Basic Plan on Ocean Policy was established. It clarified the essential of integrated management of land and coastal areas. Under the Basic Plan on Ocean Policy, each ministry engages in ICM. For example, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) promotes efforts for comprehensive sediment control. The Ministry of Agriculture, Forestry and Fisheries (MAFF) is promoting measures to prevent red clay outflow in Okinawa and other zones. The MLIT, the Ministry of the Environment (MOE) and the Fisheries Agency conduct projects on managing nutrient salts and pollutant load and restoring and promoting cycles. The MOE, the MLIT and the Fisheries Agency are promoting countermeasures against wastes drifting or washed ashore. And the

Secretariat of the Headquarters for Ocean Policy of the Cabinet Secretariat was established to implement an integrated marine policy as a multi-sector coordinating body. The Japanese coastline is about 35,000 km long and is practically divided into 7 categories: former Ministry of Construction coast, commercial port, fishing port, coast for agricultural land, co-management coast, general public coast and others. For example, former Ministry of Construction coast is about 5,000km long and managed by the Water and Disaster Management Bureau of the MLIT. The management target is coastal protection facilities such as banks. Total length of commercial ports is about 4,000km and managed by the Harbor Bureau of the MLIT, which manages port facilities, ships and boats, and sea routes. The total length of fishing ports is about 3,100km and managed by the Fishery Agency, whose management target is fishing ports and fishing boats. The coast for agricultural lands is about 1,700km long and managed by the Rural Development Bureau of the MAFF. Their management target is coastal protection facilities for agricultural lands. That is, each area is managed by different bodies who manage different targets. Each national government entrusts the management activities to local governments, however, there are no administrative boundaries within the territorial waters of Japan and there is also no national legislation in Japan that clearly delineates the offshore boundary between the coastal local government and national government. Along the coastal areas, which is wider than coastline, right-based fishing activities are conducted and licensed fishing activities are operating in the offshore which are managed by the Japan Coast Guard under the National Property Act. Regarding water resource management, the Basic Act on Water Cycle will be enacted sooner or later. The act says the water is natural heritage and establishment of an integrated water management system is needed. The national government is going to set up the Secretariat of Headquarters for an integrated water management under the Act. Currently the 7 Ministries and Agencies are involved in the Japanese water management. For instance, on land, river water and sewage are managed by the MLIT, the Ministry of Health, Labour and Welfare is in charge of public water-supply systems, industrial water and groundwater relating industrial water belong to the Ministry of Economy, Trade and Industry. The Agency for Natural Resources and Energy manages hydropower. The MOE is in charge of water quality and groundwater relating to subsidence. And management for irrigation and drainage belongs to the MAFF. In the meantime, coastal and offshore areas are managed by the 5 Ministries and Agencies as mentioned above. Moreover, spring water management, which is not currently covered by the national legislation, will become the management target under the Act. Since the study for the nexus between spring water nutrition and fisheries products in coastal waters is being developed in Japan, the need for managing spring water along the coastal areas where there is no administrative boundaries, will be recognized more and more. The purpose of this study is firstly to review coastal policies and water resource policies and secondly to consider how to develop a transdiscipline model between natural sciences and human and social sciences involving stakeholders from the beginning.

**Concentrating Solar Power and Renewable Portfolio Standards: Implications for Water Use in the West**

George Frsvold

Additional Authors: Tatiana Marquez

This study estimates how much water would be required to meet Renewable Portfolio Standards for electricity generation in five western states if 100 percent of this demand were supplied by concentrating solar power. Future renewable electricity demand (net of current supplies) is estimated for 2025 and 2035. One scenario assumes the most water-intensive solar thermal technology supplies all this future demand. Although not a feasible scenario, the assumed water intensity (1057 gallons / MWh) provides an upper-bound estimate of solar power water consumption that may be compared with regional water balances. A second scenario assumes the water intensity of future projects is comparable to the average of solar projects actually being deployed. Water intensity for these 34 projects with 8.7 GW of capacity averages 228 gallons / MWh - a lower rate than many conventional electricity facilities (coal, natural gas, nuclear). Water requirements by 2035 would be 0.8 percent of regional consumptive use of water under the upper bound scenario and 0.2 percent of consumptive use based on current, average water intensities.

**Self Supply. A promising option for water and food for millions**

Henk Holtslag

The fast growing population in developing countries requires water for drinking, domestic use and irrigation. One option to increase access is scaling up Self supply which is possible with a range of existing and new low-cost technologies or so called Smart Water Solutions (SWS). These are simple and effective options that can be produced by the local private sector resulting in a "profit-based sustainability" and availability of spare parts. Water quality can be improved by hygiene education and treatment at the household level. Water quantity can be increased by upgrading existing hand dug wells or make new wells with manual drilling technologies. The new range of technologies include options to avoid collapsing of wells, recharge 500m<sup>3</sup> of rainwater in the ground at a cost \$ 10, hand pumps to 40 meters deep at a cost of \$ 50-150, House holds water filters of \$ 15-25 etc. With these options new wells can be made or a part of the some 4 million open hand dug wells in Africa that now dry up seasonally can be upgraded at a cost of \$100-500/well and count as a MDG7 water point. Some effects of SWS: ?Bolivia. Over 40.000 family wells made with EMAS and Baptist drilling. Cost of a 15-50 m deep borehole including pump \$150-400 ?Nicaragua. 70.000 Rope pumps installed. Total income increase with these pumps was \$100 million in the 12 years. Family incomes increased \$220/year.\* ?Zimbabwe. 8300 Siphon filters were disseminated during the 2009 Cholera outbreak. None of the families who used the filter reported cases of cholera. ?Tanzania. The shift from machine drilled boreholes and imported

piston pumps to manual drilling and locally produced Rope pumps reduced the cost of water points from \$3000 to \$800. Now families buy Rope pumps for self-supply, and 95% are functioning. Self supply differs from communal supply in that families or groups of families invest themselves in water systems. To reduce poverty it maybe more cost- effective to invest in self supply than in communal water supply and reasons to stimulate Self supply are: -Communal supply as usual will not reach all, the number of unserved in sub S. Africa increased with 66million since 1990!! -Increasing population and limited local funds and less aid families invest themselves -Reduces the "eternal headache" of pump maintenance - Self supply "automatically" becomes communal supply -Leads to productive use, more income, communal supply does not. Self-supply often becomes communal supply since families will get or buy water from their neighbors. Water near the house stimulates productive use for animals, irrigation etc. A pump in the garden "automatically" increases incomes as has been proven in Nicaragua and other countries. Income generated from a household pump often benefits women and families will maintain their own pump. Eventual problems with water quality can be solved with hygiene education and a 20US\$ household water filter. SMART Centres New affordable technologies are in place; the challenge now is large scale dissemination and that requires large scale capacity building. One option to do this is via so called SMART Centres which concentrate knowledge in one place, demonstrate new options and organise training in production, quality control, marketing etc. Many technologies can be produced with local materials and the private sector can sell to NGOs but also private families. This creates employment and a sustainability based on profit so actions will go on after project funds stop. Experiences with the SHIPO SMART Centre in Tanzania after 6 years: ?20 Manual well drilling and pump companies trained ?4000 Rope pumps installed of which 30% Self supply ?Cost reduction of rural water points from \$40 to \$15 per capita Scaling up To scale up mayor fields of attention are: - Awareness. Create demand by information about the benefits and demonstration of SWS to families, NGOs, governments, others.. - Supply chain. Build up product supply chains of SWS by training local private sector in production, installation, marketing, management etc. - Financing. Provide payment options like micro credits for those who can not pay in one time. In short Self supply results economic development and so is promising option for water and food for millions.

### **Animal Welfare and the need to reframe the food security-efficiency debate**

Arjan van Houwelingen, WSPA

Animals matter to people. Over 1 billion of the world's poor depend on animals for jobs, food, income, transport, social status and cultural identification<sup>1</sup>. Good welfare practices<sup>2</sup> improve animal survival, reduce production costs and increase profits, and so enhance the productivity of the poor's main productive asset and help eradicate poverty. The fact that animals matter to all aspects of sustainable development is however seldomly acknowledged. For example, livestock is crucial to food security but unfortunately, our collective response to the growing demand for animal protein has been the expansion of low-welfare intensive livestock production and farming practices. Choosing this unsustainable path has led to a number of unintended consequences affecting: - global food security, as

grains are diverted from people to livestock; - greenhouse gas emissions, as forests and pastures are replaced by arable land for livestock feed production; - the occurrence and global costs of zoonotic diseases, such as Salmonella, E. coli, Campylobacter and avian and swine flu; and - biodiversity, as natural ecosystems and native animal habitats are destroyed and what remains is over exploited. The current global debate on sustainable development and global food security does not yet acknowledge these unintended consequences and appears to favour the business as usual approach. Reading between the lines of the General Assembly Open Working Group discussions, the High Level Panel's report as well as the most recent UN report on its global consultations regarding a Post-2015 Development Framework, the global community looks to have decided that (sustainable) intensification is the route towards achieving an end to hunger and food security for all without increasing the environmental footprint of the agricultural sector. More efficient use of natural resources is the mantra with animals considered as just another natural resource on a par with water, land, nutrients, etc. Alternate routes to achieving food security are either ignored or given lip-service at best. For instance, the issue of food loss and waste is mentioned but usually just as an afterthought even though the FAO Director-General Jos\_ Graziano da Silva recently said that the "FAO estimates that each year, one-third of all food produced for human consumption is lost or wasted - around 1.3 billion tons. This costs around 750 billion dollars annually. If we reduce food loss and waste to zero it would give us additional food to feed 2 billion people"<sup>3</sup>. Furthermore, the current failure to achieve universal food security can in part be accounted for by the lack of coordination and balance between animal-based and plant-based food production on a local, national and international scale. Globally, 53 per cent of all oil crops and 38 per cent of all cereals are used to feed livestock<sup>4</sup>. To meet the vast feed demands of industrial animal production, large areas of pasture and forest have been converted to grow crops - displacing communities, limiting the grains available for people to eat, and contributing to food price volatility. Full-scale intensification is not the inevitable future of livestock farming. It is possible to feed the world with humane sustainable farming, achieving nutrition for all by 2050 while avoiding the very real environmental and public health risks associated with intensification. To achieve this, the global community must: - include farm animal welfare in agriculture and food security assessments and policies - recognise that the industrialisation of livestock farming is a major challenge to food security - reduce the quantity of arable crops fed to livestock, especially cereals, and seek a sustainable balance between animal and crop production - promote sustainable diets and address food losses and waste in the supply chain - enhance the use of sustainable livestock production systems - consider how the Sustainable Development Goals (SDGs), their targets and indicators can support specific and regionally-sensitive measures to ensure that global food production and consumption is sustainable and incorporates respect for animal welfare principles. 1. World Bank (2009). Minding the Stock: Bringing Public Policy to Bear on Livestock Sector Development. 2. Animal welfare refers to the physical and psychological wellbeing of an animal. The welfare of an animal can be described as good or high if the individual is fit, healthy, free to express natural behavior, free from suffering and in a positive state of wellbeing. 3. <http://www.fao.org/news/story/en/item/203149/icode/> 4. Karl-Heinz Erb, Andreas Mayer, Thomas Kastner, Kristine-Elena Sallet, Helmut Haberl, 2012: The Impact of Industrial Grain Fed Livestock

Production on Food Security: an extended literature review. Commissioned by Compassion in World Farming, The Tubney Charitable Trust and World Society for the Protection of Animals, Vienna, Austria.

**Development of a Low Volume, Low Cost, Composting Septic Tank for Use in Low Water Available Environments**

Geoff Jordan, ENSOL L.L.C.

The practice of open defecation by people living in many countries and the resulting contamination of surface waterways with fecal matter, parasites and bacteria, is in turn responsible for the deaths of over 2 million people annually, mostly children less than 5 years of age. Around 800 million people globally do not have access to improved water supply sources and 2.5 billion people do not presently have access to any type of improved sanitation facility. With the sanitation need in mind, ENSOL, L.L.C. and Design4 is testing a low cost, low volume septic system based on a manure composting technology that has been used for 13 years in hog waste storage lagoons and pits. The treatment reduces stored solids, reduces odor and produces a nutrient rich effluent. In vitro testing at Iowa State University showed a 74% odor reduction. A field test resulted in a 97% reduction in hydrogen sulfide gas emission from a deep storage hog slurry tank. A packaged septic tank treatment that enhances the performance of a septic system, dissolves sludge and provides a nutrient enhanced effluent, which when dispersed through a leach field or land applied has been shown to multiply beneficial crop growth. The treatment packs, trade named "DOWN JOHN", have been sold to USA householders over the last 12 years with excellent anecdotal testimonials from customers, as to odor control and trouble free overall septic system operation. The "DOWN JOHN" treatment neutralizes toxins by adsorption onto activated carbon, which itself provides a massive surface area for bacterial growth. A proprietary blend of mostly anaerobic bacteria is then added and the biomass concentration is maximized. Included lipase enzymes eat any dietary oils or fats. American families use about 280 gallons of water per day compared to 5 gallons of water used by the average African family. Therefore, septic tanks in the USA need to be about 1,000 gallons minimum to cope with the daily load from toilets, showers, kitchen, dishwashers and clothes washing machines. Plans are being made to produce a low cost, low volume (70 gallon) dual septic system for the African and developing world context, that can be installed using a mechanized post hole digger and using prefabricated heavy gauge tubular polyethylene for the tanks. Above the tanks is a squat stool and WC enclosure for privacy and a second tank discharge to a leach field or collection tank. A test rig of three individual dual tank septic systems of this innovative type (Tube Toilet) has been constructed and is being tested at Oklahoma State University to gather empirical data and to determine its efficacy in composting feces and urine from segregated hogs being fed an African equivalent diet. The availability of a low cost, easily installed septic tank system is seen as a feasible means of containing bacterial and parasitic disease, reducing pathogens and thereby protecting surface waterways and reducing infection among the population. The "Tube Toilet" would bring the cost of a private toilet down from \$550 average per stall to \$100 per stall -- which, in combination with access to loan capital, makes the system affordable to the rural and urban poor. The possibility of crop



enhancement using the generated nutrient enhanced effluent may provide further economic benefit. Research by Makerere University in Uganda shows the poor are 8 times more likely to use a private latrine than a shared or public latrine, and almost 4 times more likely to keep it clean. The first round of tests is scheduled for completion by February 15, 2014 and if accepted, the results will be written up and our paper presented at the Nexus Conference, in March 2014.

### **Verifying precision irrigation's ability to reduce water use**

Jason Kelley, Oregon State University

As the largest global use of diverted surface and groundwater, irrigated agriculture will require dramatic improvements in water delivery and application to address future water availability. Variable rate irrigation (VRI) is one technology proposed to improve efficiency in water distribution systems in agriculture. Using explicit distribution maps and automated control systems, VRI allows application of water to fields precisely where needed, ideally reducing overapplication and assuring adequate irrigation. Implementing VRI systems can also reduce fertilizer application rates in fertigation systems. Improvements in irrigation efficiencies of up to 26%, and reductions of fertilizer application of 46% have been reported. However, the potential for this improvement is constrained under field conditions by environmental factors and equipment performance. To identify spatial limitations on the scale of precision, four field experiments were conducted with center pivots equipped with VRI under real world farming conditions. The results of these experiments have been parameterized to a performance coefficient derived similarly to the Heerman and Hein uniformity coefficient. This performance coefficient is applied here to compare the order of magnitude of potential improvements from VRI, compared to the gains from other conventional improvements, such as improving water transmission systems, upgrading pumping systems, and water saving strategies such as deficit irrigation. By identifying the minimum management scale, VRI systems can be designed with feasible outcomes, allowing the appropriate allocation of resources to developing this technology.

### **Obe Drop's Integrated Approach to Water Conservation and Management for Food Security in climate change sensitive areas**

Nadia Koukoui, ONE DROP

The rural communities of Cacaopera and Corinto, in the Morazán department of El Salvador, are located in a dry tropical zone characterized by an extended dry season lasting up to 6 months, followed by intense and irregular rainfalls. In the dry tropics of Central America, such precipitation patterns are highly influenced and accentuated by the El Niño and La Niña climatic phenomena, often associated with droughts and floods, respectively (1). Indeed, scientific studies conducted by the Inter-governmental Panel on Climate Change (IPCC) are predicting a decrease in mean precipitation accompanied by an increase in mean temperature by 2100 for this region (2). As rain fed agricultural production of cereals

and beans constitutes the staple for the region, this precarious hydrological situation, exacerbated by detrimental anthropogenic activities on the environment, makes water access and agricultural production difficult to achieve during the rainy season and virtually impossible during the dry season. This situation seriously compromises the survival and socio-economic development of these communities.

Within the scope of a 6 year long project, the Montreal-based non-governmental organization ONE DROP is working with the Cacaopera and Corinto communities to increase their resilience to climate change and ensure water and food security. ONE DROP's novel approach to WASH programs was used to tackle the communities' water scarcity and food security issues in a sustainable way. ONE DROP's approach is an inter-disciplinary and holistic approach based on three complementary components: a social arts and popular education component to raise collective awareness, educate and mobilize the local population around environmental protection activities, better water management practices and development opportunities; a technical component to improve access to drinking water and irrigation, and improve overall sanitation and hygiene; and a financial inclusion component including microfinance and other economic opportunities for livelihood sustainability. Moreover, ONE DROP's approach focuses on the protection and better management of existing water sources, rather than on the development of additional infrastructure.

ONE DROP and its partners conducted interactive workshops and plays based on local customs and culture. These activities allowed raising community members' awareness and understanding of the impacts of poor environmental practices, such as deforestation and contamination of water sources, on the availability and quality of natural resources. Community members gathered, discussed and discovered opportunities for social transformation and economic development, which created a sense of individual as well as collective empowerment and responsibility. Moreover, infrastructure development and land cover changes were introduced as water conservation techniques. Fruit trees were planted to reduce soil erosion, and enhance runoff infiltration and aquifer replenishment during the rainy season. Cultivation gardens were constructed for subsistence farming; these were equipped with micro-drip irrigation systems connected to rainwater harvesting units so as to ensure a continuous supply of water during the dry period, and thus ensure food security. In addition, ONE DROP introduced energy-efficient ovens as a climate change mitigation strategy, which helped decrease deforestation rates by approximately 55%. The introduction of energy-efficient ovens also reduced the amount of time spent by women on wood cutting chores, and improved air quality in the dwellings. Moreover, ONE DROP initiated a microfinance program in collaboration with local financial institutions so as to enable farmers and entrepreneurs to engage in sound and viable agricultural and commercial activities. Business plans were developed and technical training was provided to reinforce the sustainability of the microfinance program. Micro-loan beneficiaries were able to generate profits and considerably increase their income, thus ensuring financial security for their families. This project demonstrated the applicability of the approach in addressing food, water and environmental challenges in areas sensitive to climate change. Since the start of the project in October 2010, on-site investigations revealed an

increase in crop harvest frequency, as well as an increase in families' yearly income for those benefiting from the microfinance program. In conclusion, the approach is a promising model for the sustainable development of remote and climate sensitive areas.

**Comprehensive Case Analysis on Participatory Approaches Applied to Resolve Environmental Disputes in Local Community from Nexus Perspectives**

Naoki Masuhara, Research Institute for Humanity and Nature

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Our research aims to explore solutions for conflicts in the context of water-energy-food nexus in local communities by using participatory approaches. To achieve it, we clarify drivers and barriers of each participatory approaches applied so far in water, energy and food policy, focusing on how to deal with scientific facts by doing comprehensive case analysis. Based on the above result, we are designing and implementing participatory approaches in local communities to realize "co-design and co-production of science and society." The participatory approaches such as consensus conference, deliberative polling(R), "joint fact-finding" and so on have been applied to resolve various environmental disputes so far, however the drivers and barriers in such processes have not been necessarily enough analyzed in a comprehensive way. We generate hypotheses primarily that multi-issue solutions through policy integration will be more effective for conflicts in the context of water-energy-food nexus than single issue solutions for each policy. One of the key factors to formulate effective solutions is to integrate "scientific fact (expert knowledge)" and "local knowledge". Given this primary hypothesis, more specifically, we assume that it is effective for building consensus to provide opportunities to resolve the disagreement of "framing" that stakeholders can offer to experts the points for providing scientific facts and that experts can get common understanding of scientific facts in the early stage of the process. To verify these hypotheses, we develop a database of the cases which such participatory approaches have been applied so far to resolve various environmental disputes based on literature survey of journal articles and public documents of Japanese cases. In developing this database, we provide the indicators set to evaluate each process and outcome with reference to the previous studies (e.g. Webler, 1995; Rowe et al., 2000; Baba, 2002; Beierle, 2002, Murdock, 2005; Chilvers, 2008) such as characteristics of the issues (multi/single), legitimacy of the process, the way of providing scientific facts (expert knowledge), procedural justice (representativeness, deliberativeness, accessibility, adjustability, faithfulness). Finally, we analyze the relationship between the process and outcome with statistical analysis like correspondence analysis to clarify a general trend on the drivers and barriers in such processes.

**Ensuring food security in India through efficient water management: Challenges under a changing climate**

Shadananan Nair, Nansen Environmental Research Centre

Ensuring food security for the fast rising population is a major challenge in India. Even with developments in the irrigation sector, farming in large area is still monsoon dependent. Variations in monsoons seriously affect agriculture and thereby the national economy and rural life. Rainfall is becoming increasingly seasonal, making dry season longer and reducing groundwater recharge. About 80% of Indian agriculture depends on groundwater. As a result of the increasing frequency and intensity of tropical storms, storm surges move far inland, salinating coastal aquifers. Rising sea level may worsen this in future. Change in rainfall seasonality and intensity cause erosion of the already degraded soil in the Western Ghats Mountain. Sedimentation considerably reduces the capacity of reservoirs and pre-monsoon runoff in rivers. Several rivers are becoming seasonal. States in this region that largely depending on hydropower face energy crisis. Retreat of the Himalayan glaciers may affect the existence of major rivers in north India, leading to water crisis and famine in near future. Small increase in regional rainfall in certain parts may not be able to compensate for the loss in soil moisture due to rising temperature. Anthropogenic impact on water resources add to the climate change impact. Water resources are being fast deteriorated and depleted because of pollution, overuse and encroachment. Due to the destruction of wetlands, sand quarrying and overextraction, groundwater level all over India is fast declining. Agricultural area is shrinking due to encroachment and land degradation and productivity is decreasing due to overuse of fertilizers and over irrigation. Government policies prioritise industries over agriculture. Recent government reports warn that India is heading towards a food crisis. Shortage of water and setbacks in agriculture initiate social issues such as conflicts over water allocation, migration. Poverty of the agriculture depending rural communities promotes extremism. Because of improper conservation and management, large part of the runoff wastefully flows into the seas. Optimum utilisation of this runoff and the still unutilised groundwater potential, schemes to conserve surface water resources, measures to recharge groundwater and proper climate change adaptation strategies can save India from the crisis. This paper analyses the impact of climate change and anthropogenic activities on water resources of India and its reflections in the agricultural sector. Changes in water availability in an altered climate have been estimated using hydrological model. Existing policies, strategies and management issues have been critically reviewed. India urgently needs an appropriate strategy for land and water management and climate change adaptation and a comprehensive policy for agriculture, water and climate and an efficient mechanism for their implementation. Guidelines for this have been provided.

**A Conceptual Twofold Risk- Resilience Approach to Evaluate Security of a Water Environment**

Pedcris Orencio, Research Institute for Humanity and Nature

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The concept of security has shifted, through time, from a state-focused to an individual-centered paradigm. The shift followed a two-level transformation process where the center of gravity was transferred from territorial security to people security and the means for achieving security changed from weapons procurement to sustainable human development. This new view has created the link to the protection of the vital core that influences human welfare and well-being, which is an ultimate right of any individual. However, putting the new security into practice entails facing many challenges. Its conception created multiple views ranging from various domains of well-being such as health, education, income, political freedom and democracy, and the different conditions of safety from direct and indirect threats to core human values. It is believed that a secured individual is somebody who could pursue his core rights within the metes and bounds of freedom and capability by carrying out life's activities, while the activities were maintained by a series of favorable conditions. A great deal of security is tied to people's access to natural resources and vulnerability to environmental change, which is directly or indirectly affected by human activities and conflicts. Likewise, significant processes of social and natural interactions have influenced the patterns of protection and management of resources. Among the most salient of processes are brought about by rapid industrialization, urbanization and global climate changes. Industrialization, despite positive in effects, could influence potential disaster agents that hasten the risk of highly vulnerable societies. Climate change, on the other hand, has been found to cause variability in large scale environments, particularly impacting resources for food, biodiversity, human health and livelihoods. Among the many environments, water is regarded as the most essential and yet is still directly threatened by human activities and anthropogenic climate changes. In most cases, land cover change and engineering schemes that were often conducted to provide humanity with access to water resources are the major threats to water. The resource is further influenced by climate variability such as rainfall and temperature changes. One output of changes is water scarcity, which could impact security as it is linked to the overall concerns of food production and sanitation thereby affecting human survival, well-being and productivity. In short, the impacts of changes to water environment and the key resources it provides will affect basic human needs and development. The water environment does not only provide water but also resources for food and energy. Hence, even the Millennium Development Goals (MDG) puts critical importance on the progress in water management in order to fare with all known potential impact of its changes to all aspects of human existence. This recognition of relationship between water and humanity needs has brought about interests in evaluating water vulnerability. In fact, it has gained ground as a necessary step in water resources planning and policy development. Nonetheless, in the light of imminent changes in water quality and quantity, a need to develop coping mechanisms and strategies for adaptation is crucial. In this paper, the authors would like to argue that a focus on risk and resilience of humanity to

changes in resource, as influenced by hazards and threats from environmental and social changes, could present a better view for a conceptual evaluation of security. To the extent possible, we present our arguments in the area of water environment and its related resources for providing water, energy and food. The objective is to develop the concept procedurally and contribute to a more feasible and appropriate evaluation across various economic developments, environmental management and human conditions. A twofold evaluation approach that looked at the notion of risk and resilience concepts was designed within the context of who is vulnerable, how actions of people and conditions affect vulnerability and resilience, and what actions were done to reduce or mitigate potential effects. Vulnerability is based on susceptibility of a system to damage as a function of exposure to different stressors and its consequences. Susceptibility is equivalent to sensitivity, which is a precondition to suffer from harm because of some level of fragility or disadvantaged situation, and may be expected to increase with exposure. Resilience is the ability of both social and environmental systems to resist, absorb, accommodate to and recover from the effects of external factors based on necessary resources for preservation and recovery. To present a world view of these concepts, a case of differing economies, humanities and environments were used to illustrate the twofold approach in a water environment in the Asia-Pacific Ring of Fire.

#### **Evaluating Water Quality and Quantity for Rain Catchment Systems on Urban Farms**

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Urban based agriculture is emerging as one of the most important elements to secure the growth and demands for local food production especially in metropolitan areas across the U.S.. Establishing urban small-scale farms shares some of the same risks experienced by more traditional farming enterprises outside cities such as the uncertainties of markets, capital and natural hazards like droughts. Yet, the location of urban and peri-urban agriculture poses distinct challenges to starting a farm. Start-ups in U.S. cities have experienced surprising difficulties in securing permanent, affordable water sources permitted to serve agricultural irrigation demands. This Project and field work is a collaboration between Rain Catchers LLC, a Designer and Installer of underground rain catchment systems powered by solar and researchers at NCSU. The Project examines the water quality of selected indicators before and after throughput in a Rain Catchers System related to microbial contamination and problems of nutrient loading. Shedding light on how underground rain catchment systems improve or alter water quality and provide adequate water quantity is important for the sustainable future of urban farming and alternative water use that does not depend only on city treated water.

### **A Nexus Perspective from the Hindu Kush Himalayan Region**

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Abstract With limited land resources, inadequate energy supply, and growing water stress, much of Asia faces the challenge of providing enough water and energy to grow enough food for the burgeoning population. The nexus approach is extremely relevant to Asia as the region has to feed two-thirds of the world's population (4.14 billion people) and accounts for 59% of the planet's water consumption. Ensuring food security and providing access to safe drinking water and modern energy for all remains a key challenge for Asia's sustainable development. The Hindu Kush Himalayas provide ecosystem services that are critical for water, energy, and agricultural sustainability and productivity in Asia. All of the subregion's major rivers and their numerous tributaries originate in the Himalayas with about 1.3 billion people relying on freshwater obtained directly or indirectly from the Hindu Kush Himalayan (HKH) mountain systems. These ecosystems are under increasing pressure from changing resource use and climate change. Recent flood events raise questions as to our preparedness to face these changes. Failure to recognize the value of HKH ecosystems results in inadequate measures to manage the water supply of the posing a serious threat to the sustained flow of ecosystem services critical for food, water, and energy security in the HKH and downstream. Most of the major rivers of the HKH region are transboundary and managed at multiple scales – local, national, and regional – and governed by diverse stakeholders. Moreover, increasing uncertainties are brought about by climate change, having a direct impact on supply with changes in glaciers, snowpack and monsoon patterns. Increased variability of supplies, requires new ways of thinking about managing demand and use of water resources. New systematic efforts are needed to understand the spatial and regional dimensions of the nexus including the spatial patterns of resource availability and use, how resources flow, upstream-downstream linkages, and the potential benefits of addressing challenges through regional and river-basin approaches. More attention is needed on the upstream-downstream linkages of ecosystem services, biophysical and socio-economic interdependencies, and the importance of cross-scale coordination in managing nexus challenges. Since different countries have different resource endowments and face different challenges in managing the nexus, upstream-downstream coordination can tap the potential of synergies in transboundary river basins, which is well illustrated in the HKH region. Using secondary data from diverse sources, this paper explores the food, water, and energy nexus from a regional dimension, emphasizing the role of Hindu Kush Himalayan (HKH) ecosystems in sustaining food, water, and energy security downstream. The analysis reveals that the issues and challenges in the food, water, and energy sectors are interwoven in many complex ways and cannot be managed effectively without cross-sectoral integration. The most distinctive feature in the region is the high degree of dependency of downstream communities on upstream ecosystem services for dry-season water for irrigation and hydropower, drinking water, and soil fertility and nutrients. With climate change, there is additional uncertainty regarding the water supply as well as demand, and new questions are posed regarding the sustainable

management of water. For example, attention needs to be paid to reducing black carbon emissions to retain the freshwater benefits of the Himalayan glaciers. This can be done by providing alternative energy sources to rural people to minimize use of biomass for energy and by improving kiln efficiency in the brick making industry. In meeting the growing energy needs, clean energy options such as micro and macro hydropower require attention however with due consideration to the full range of benefits and costs. Along with cross-sectoral integration to improve the resource-use efficiency and productivity of the three sectors, regional integration between upstream and downstream areas is critical in food, water, and energy security in the face of change. Within the nexus approach adequate attention is required on the management of HKH ecosystems - especially the watersheds, catchments, cryosphere, headwaters and atmosphere of river systems - and to tapping the potential of collaborative gains in water, hydropower, and other ecosystem services through coordination across HKH countries. Key words: Water-food-energy nexus, ecosystem services, upstream-downstream linkages, Hindu Kush-Himalayan mountain systems

**Reliability of Rainfall for crop production. A case study in Uganda**

Nansubuga Resty, Makerere University

Drought has occurred in various parts of Uganda many times seriously affecting crop production, food market prices and ultimately, the cost of living (NEMA, 2001). Uganda's population is sustained by crops, which are largely produced under rain fed conditions. In recent years, however some areas have experienced significant drought. This phenomenon requires the attention of those involved in the formulation of agricultural policies. To address some of these concerns, a study was carried out to determine the reliability of rainfall in relation to crop water requirements, for different crops in climatic region in Uganda. Available rainfall data from these regions were examined for consistency using the double mass curve and in filled using Markov generation methods. The data was then subjected to statistical tests to determine the probability distributions that best fit them. Probability distributions were selected from among the Log-Normal, Pearson types and the Gumbel Extreme Value Type I distributions. Two methods were applied in determining the most suitable distribution, namely, the Chi-square test and regression analysis. Representative crops from the districts were then selected and their crop water requirements determined. These were compared to the rainfall to determine the effectiveness of the rainfall in meeting crop water requirements. The crop water requirements were adjusted with respect to the effective rainfall to find a planting date that minimizes the additional water requirement. Crops that required additional water were identified and the yield reduction due to moisture stresses determined. Irrigation schedules were then developed for the crops that required additional water. Keywords: crop water requirements, Chi Square test, probability plot, rainfall reliability, return period, yield reduction



**Social stratification and drinking water crisis in southwest Bangladesh**

Luisa Fernanda Roldan Rojas

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There are 768 million people in the world confronting with drinking water crisis. The appearance of drinking water crisis has posed as a public health hazard having a very significant impact on people's life, health, social and economic activities in developing countries, particularly in Bangladesh. In fact, the arsenic and salinity contamination of groundwater and surface water has created additional burden in the rural water supply management demanding water treatment and water quality surveillance. The magnitude of this problem demands for extensive research to overcome the worst situation of drinking water crisis in the country. Water scarcity is in the one hand because of natural conditions which difficult the water availability in some areas; in the other hand because of man-made consequences, like the polluted water resources and the financial incapability of arranging safe or drinking water supply. Though the affect of not having drinking water is similar to every single person, the perception about water crisis varies according to their socio-economic conditions, their location (proximity to water source), as well as the involvement of different stakeholders in water sectors. Based on empirical evidence from Bangladesh this research explicitly explores the socio-economic dimensions of water crisis, with the aim to use the drinking water crisis as a tool for analyzing the social classification in the southwest coastal villages of Bangladesh. By following a simple random sampling method, a questionnaire survey was conducted with 274 households to evaluate their existing drinking water situation, their attitude and perception on drinking water crisis. It is given that drinking water is an unavoidable problem for all the people living in the study area and most of the respondents consider the water crisis as a cause of social and health problems. According to the respondents the existing drinking water sources are tube-well, pond and Pond-Sand-Filter (PSF). This research considers the social classification as an approach of drinking water vulnerability analysis. Particularly, based on the most relevant social indicators the respondents were classified into three social clusters: cluster 1 represents the illiterate with an average monthly income of less than 5000 BDT, they are mostly agricultural workers and housewives; cluster 2 is for the people with a low level of education, an income of less than 5000 BDT and includes the agricultural workers, housewives and small-traders; and cluster 3 stands for the educated people, having an average monthly income of more than 5000 BDT, literally they are the businessman, and service holders of the community. And vulnerability of drinking water is determined by the accessibility, quality (saline/arsenic) and sources of water. Unfortunately, the basic facts in Bangladesh are that the people in the study areas are still ignorant about drinking water crisis and its hazardous effects. Besides, most of the existing water sources are contaminated with arsenic and/or salinity. Respondents were bound to use those polluted and contaminated water, the reason for the use of contaminated water is the limited access to other water resources (infrastructural and time-distance). There are different perceptions to solve these problems: for example, the users of PSFs realize the need of filters to remove the salinity. But in the case of the tube-wells users, people with a low income and

low level of education tend to perceive the construction of more tube-wells as a solution, without to take into account the probability of obtaining new tube-wells, which water would also contain arsenic or salinity. The governmental efforts are much less than needed to mitigate the crisis. Hence, the immediate involvement of international community is urgent to combat the slow onset disaster and save the poor people. It is expected that results will confirm the hypothesis that drinking water crisis management strongly depends on social-power-structure and their role in community disaster management approach. Results confirm the hypothesis that drinking water crisis management strongly depends on social position of the individuals and the participation in local community development programs. It depicts that poor and power-less people differ significantly in usages of water. Thus, this research props up new dimensions of social vulnerability analysis and results into possible locally adopted strategies to mitigate drinking water crisis

### **Gender Disaggregated Payments for Ecosystem Services along Slopes of Taita Hills, Kenya**

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Payments for ecosystem services (PES) policies compensate individuals or communities for undertaking actions that increase the provision of ecosystem services such as forest conservation, flood mitigation, or carbon sequestration. PES schemes rely on incentives to encourage behavioral change and can consequently be considered part of the broader class to stimulate market based mechanisms for environmental policy. The research was conducted in six sub locations along the slopes of Taita hills, at least two sub locations were surveyed in each altitudinal zone namely lowlands(850 m), midlands(1500 m) and highlands(2100 m). Specifically, the study intended to find out minimum amount of money households are willing to accept (WTA) as compensation every year as a trade-off between conservation of forest ecosystems and the ongoing social economic activities taking place in the study area and how they differ between gender, altitudinal gradient and majority/minority groups. A contingent valuation method was used to elicit 172 households. Findings showed that, aggregate mean WTA was USD 314.26 per household per year, although altitudinally was increasing from low, mid to highlands (USDs 217.20, 310.97 and 429.84 respectively). Female headed households showed relatively higher mean WTA as compared to male headed households; however the difference diminished as you go to higher altitudes (USDs 53.26, 29.19 and 6.74). Likewise old and disabled headed households had relative higher mean WTA as compared to other household's categories. The study concluded that, mean WTA differ statistically significant between altitude and gender. Therefore, it recommends that, PES programmes have to take into account on gender, minority groups and altitudinal gradients when implementing related programmes. This enables lowering costs, in conjunction with meeting the interest of the resource-poor households and the national/global interests on ecosystems and biodiversity conservation around the mountainous critical ecosystems. Key words: WTA, gender, altitudinal gradient.

### **Nexus Approach and Post-one-size-fits-all Approach for Sustainable Development Goals (SDGs)**

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Setting Sustainable Development Goals (SDGs) with international agreement is an important, urgent task for the international society after the Rio 20 Conference in 2012. Development of indicators to measure the progress of achieving SDGs (hereinafter, referring as "SD indicators"), is another task. There are several challenges to set SDGs and develop SD indicators. This study focuses on two among them. One challenge is to take nexuses, interlinkages, between elements of sustainable development, into account. A traditional approach of the use of sustainable development indicators by countries lacks views on how different activities/phenomena are interrelating to each other. Tasaki et al. (2010) reviewed 1,790 SD indicators set by countries and identified that two of five major tasks of future development of SD indicators were "measuring interactions between elements of a system" and "dealing with transboundary issues in a national SD indicator system". These findings suggest that an approach taking nexuses into account is needed. Without such an approach, it would be difficult to create a motive - preferably incentives and mechanism as well - to balance our various activities and to put them within the planetary boundaries (Rockstr\_m, 2009). Not only such planetary well-being, we need to pursue human well-being as well, and nexuses between such objectives of human well-being as Millennium Development Goals (MDGs) set are needed to be paid attention (e.g., Griggs et al. (2013) proposed six areas of such integrated goals). Otherwise, effective human development would be undermined. The water, energy and food security nexus (Hoff, 2011) is one of such nexus that we should pay attention to. But there would be other nexuses we should be aware of. Especially, the nexus mentioned above is a human-centric and focusing on human security only. We also need to look upon nexuses (or balances) between human well-being and planetary well-being. With this in mind, we tried to identify important nexuses using a matrix of 77 categories of national SD indicators and additional words associated with "sustainability" that were found on the web. Our trial suggested that the number of interlinkages was enormous and it was difficult to reduce the number and identify important ones in this systematic way. This led us to examine different types of nexuses/interlinkages. We described different types of nexuses/interlinkages on a theoretical basis. These include intermediate and final linkages, multiple inputs and outputs, synergies and trade-offs, and linkages between objective (real) elements and subjective elements (perception). This distinction implied the importance of looking at criteria for sustainable development. We therefore reviewed criteria used in various activities for sustainable development as well as the Daly's operational principles of sustainable development (Daly, 1990). Accessibility, efficiency, diversity, reversibility, etc. as well as security would be basic axes of the criteria for sustainable development. Using these axes of the criteria, we tried to identify important nexuses with the matrix mentioned above. The detailed results will be presented. The other challenge is to find post-'one-size-fits-all' approach, which was used for the Millennium Development Goals (MDGs) and criticized sometimes. There have been differences in the objectives of a society between countries,

especially between developed and developing countries - The priority of relying on the criteria of sustainable development differs. International society, therefore, should develop a new framework to set 'differentiated but common goals' for SDGs. In this context, we looked at specific SD indicators developed by different countries/organizations under each sustainability issues (e.g., energy), and categorized them from the viewpoint of development levels based on our 1,790 SD indicator database, and categorized the indicators. The result of preliminary analysis showed some common trends among different sustainability issues, such as tendency to focus more on efficiency and less on accessibility as countries develop. The detailed results will be presented.

### **The Role of Water and Good Health in Food Security in Sub-Saharan Africa**

Robert Tortora, Gallup

Additional Authors: Magali Rheault

This paper examines 2010 data from 17 countries in the Gallup World Poll about the frequency gauging the prevalence of food insecurity in sub-Saharan Africa. First, the validity of this the pollsurvey's self-reported measure of food insecurity is established. Then, this measure is then used as the dependent variable in a multivariate regression analysis, with independent variables including self-reports of experiencing health problems, having their access to sufficient drinking water and people's perceptions of the availability of water for drinking and for agriculture, as well as while controlling for several demographic factors included as control variables. The results demonstrate that the availability of water for drinking and agricultural purposes and the absence of health problems, as well as education, income and urbanization all influence predict the food-security status of the sub-Saharan African households surveyed.