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SUSTAINABLE WATER FUTURE PROGRAMME

Proceedings of
the 3rd Future Earth
Water-Energy-Food Nexus Workshop

Governance transformation and integrated information for the W-E-F Nexus

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Prepared by:
Richard Lawford
Aiko Endo
Claudia Pahl-Wostl
Parmeshwar Udmale

Preface

This report from the third regional workshop of the Future Earth Water-Energy-Food (W-E-F) Nexus Cluster study marks a significant milestone in the study. The results of this study will be a synthesis of four regional workshops including this event along with two that have already been held in the United States of America and Germany, and one that is being planned in South Africa. The W-E-F study is funded by the Belmont Forum and administered through the Sustainable Water Future Programme Office located in Brisbane Australia,

This workshop was held on April 4 to 6, 2016 at the Research Institute for Humanity and Nature (RIHN) (during the peak of the cherry blossom season.) Approximately 45 experts from three continents gathered to share their views on the W-E-F Nexus in Asia and the potential contributions of improved governance and integrated information systems to support sustainable coordinated management of food, energy and water resources in the critical areas of Asia. In addition to exploring the topics discussed at previous workshops as they relate to Asia, the workshop featured discussions of the needs and approaches for developing a definition and taxonomy for the W-E-F Nexus; aquaculture as a source of food, and challenges in providing economic stability for small farmers. Ideas about specific research projects will be followed up in the region and more broadly. Discussions about the contribution of this project to Future Earth programme focused on the Future Earth FEW Knowledge Action Network and the SDGs. This report provides short descriptions of the presentations and summaries of the panel discussions, plenary sessions, and breakout groups which occurred at the Kyoto workshop.

Acknowledgements

The support of RIHN, its director general, Prof. Tetsuzo Yasunari, the director of the Future Earth Regional Center for Asia, Prof. Hein Mallee, and the deputy director general of RIHN, Dr. Makoto Taniguchi, are gratefully acknowledged. Dr. Aiko Endo, the leader of RIHN nexus project (No.14200097), served as an active member of the organizing committee but also arranged the logistics at RIHN. The work of Parmeshwar Udmale, and Maximilian Spiegelberg, in providing notes from the discussions at panel discussions and plenary sessions are greatly appreciated. Ms. Andrée-Anne Boisvert and Mr. Shun Teramoto provided appreciated technical editing for the report. Finally, the support of the Sustainable Water Future Programme Office and the National Science Foundation through the Belmont Forum is gratefully acknowledged.

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Monday, April 4, 2016

Welcoming remarks

The introductory session of the third Future Earth Water-Energy-Food (W-E-F) Nexus Workshop, chaired by Dr. Aiko Endo of the Research Institute for Humanity and Nature (RIHN), opened with a greeting of all participants.

Welcoming remarks were given by Dr. Taketoshi Taniguchi, Deputy Director General of RIHN, on behalf of Dr. Tetsuzo Yasunari, Director-General of RIHN.

Introduction of Future Earth W-E-F Project and the purposes of this workshop

Richard Lawford of Morgan State University presented a comprehensive overview of the Future Earth Water-Energy-Food Nexus Cluster Project, including the Global Water System Programme (GWSP) and Sustainable Water Future Programme (SWFP) Nexus initiatives. He briefly explained that the GWSP Global Catchment Initiative (GCI) analysed the Water-Energy-Food Nexus in nine basins addressing market-driven, development agenda-driven, and political change-driven basins. In addition, GWSP, the European Space Agency (ESA), and the Food and Agriculture Organization of the United Nations (FAO) organized a working group on Earth observations and the W-E-F Nexus in March 2014 in Rome, Italy to review the role of Earth observations in the W-E-F Nexus. The working group also recommended the “W-E-F Community” to implement priorities that are aligned with the relevant emerging Sustainable Development Goals (SDG). In May 2014, GWSP and the United Nations Environment Programme (UNEP) held a workshop in Bonn, Germany to discuss optimal governance of the W-E-F Nexus to focus on solutions.

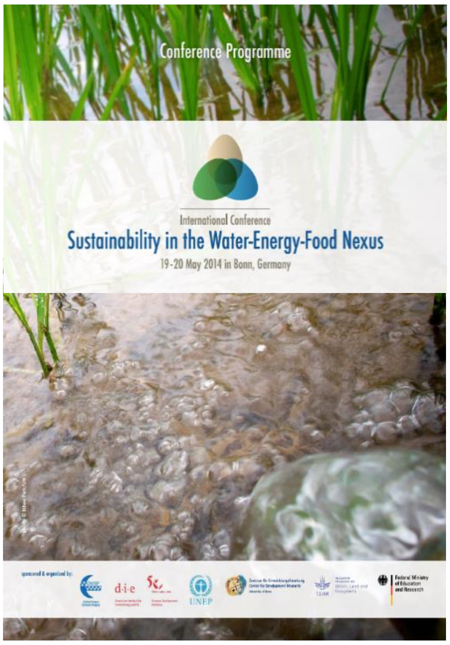

Figure 1. The Bonn 2014 Nexus Conference.

In 2014, a successful proposal was submitted by Dr. Claudia Pahl-Wostl and Richard Lawford, along with other GWSP Science Committee members and a number of other co-authors, to the Belmont Forum. The goal of the resultant two-year Future Earth Cluster project is to explore the use of integrated information and improved governance to enhance the sustainability of the W-E-F Nexus, on the hypothesis that the needs for science, governance, technology, observations, and information systems can be effectively related to the current structure and possible future structures for the energy and agricultural industries and water services. Furthermore, the W-E-F community has the tools, data, and expertise to meet these needs once they have been fully identified.

The first W-E-F Cluster workshop, sponsored by Texas A&M University and SWFP, was held in Washington, DC, on June 1-3, 2015, with 75 participants. Efforts began to develop a U.S. W-E-F Community of Practice and for the U.S. National Science Foundation to incorporate some workshop findings into its upcoming call for proposals.

The second workshop was held in Karlsruhe, Germany on November 23-25, 2015. It focused on the need to better understand European issues, particularly in the energy area.

The priority questions of the third workshop include:
- Asian W-E-F Nexus issues and their links to global issues.
- Interlinkages between land and sea under the W-E-F Nexus framework.
- Asian approaches to data collection and information and decision support on different spatial and temporal scales.
- Links between information, the W-E-F Nexus, and ecosystem management in the Asian context.

Introduction of the SWFP

Dr. Pahl-Wostl summarized SWFP, which was organized under three major themes based on calls for a reality-based and multi-scale knowledge-to-action water agenda, as follows:

A. State of Global Water
  - Knowledge concerning the global state of water.
  - Assessing risks to humans and the global water system through appropriate risk-related metrics.

B. Governance of Transformation
  - Dynamic society-nature interface and interactions at and across different scales.
  - Addressing institutional landscapes, actor networks, and the multi-dimensional valuation of water and its services.

C. Water as Global Change Agent
  - The W-E-F Nexus, the water-carbon link, and interfaces with water and health and water and biodiversity issues.
  - Water as an agent transmitting global change effects and its critical role in the development agenda.

Because existing global water resource assessments are inadequate to monitor water-related SDGs and complex decision-making, SWFP targeted global water system assessments focusing on the SDGs. Dr. Pahl-Wostl also introduced plans to develop the Water Solution Lab Network (WSLN), which will integrate scientific and practical knowledge and support a demand-driven innovation process that will result in lasting and effective solutions to water-related problems. Target audiences, for example, will be national and global science bodies for science, industries for science application, development organizations for implementation, and policy makers at the UN and national levels for science policy. To achieve this goal, working groups on water and health, the global hydrological cycle, sustainability in the Nexus, rivers in the Anthropocene, virtual water, deltas and sediment, transboundary water governance, risk assessment threat mapping, water quality, water governance, urban water systems, and groundwater will be established under the planning committee for transition.

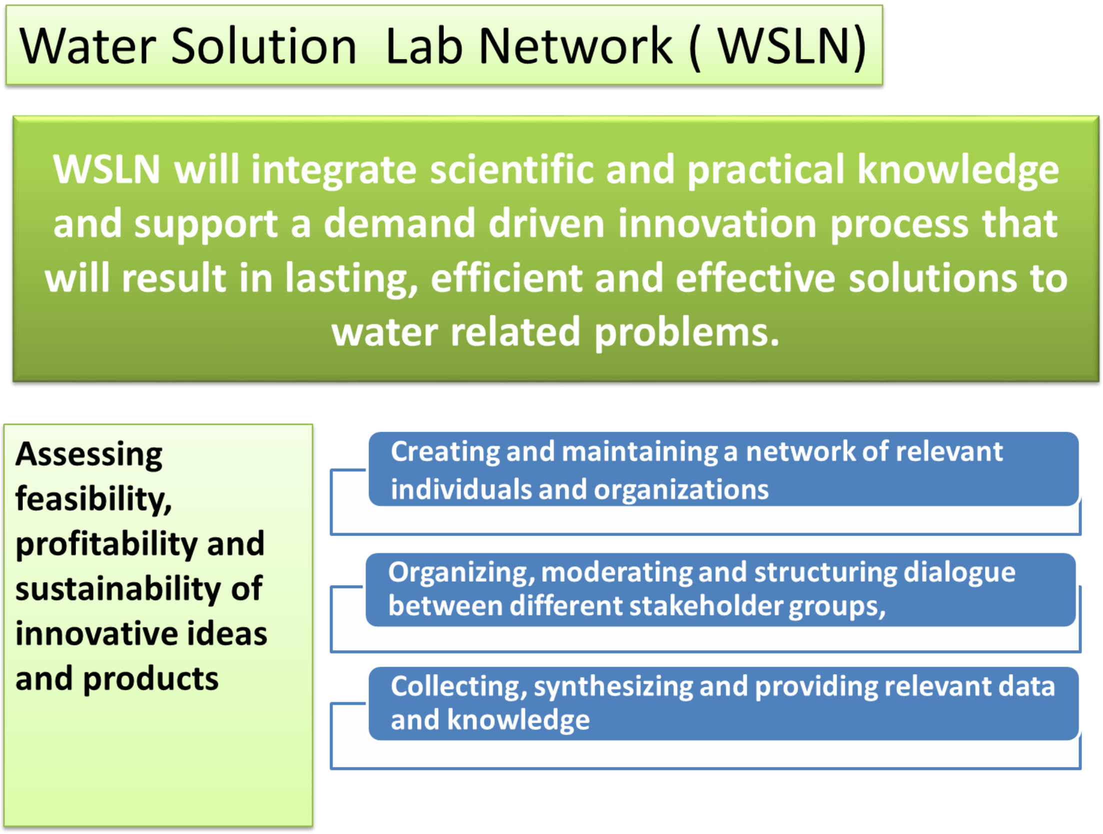

Figure 2. Water Solution Lab Network (presented by Dr. Pahl-Wostl).

Introduction of the Future Earth and Nexus

Dr. Makoto Taniguchi briefly introduced Future Earth and the Nexus by providing its history and collaboration links. International global environmental research has been promoted based on four existing programmes on global environmental change:

1) The International Geosphere-Biosphere Programme (IGBP)
2) The International Human Dimension Programme on Global Environmental Change (IHDP)
3) The International Programme on Biodiversity Science (DIVERSITAS)
4) The World Climate Research Programme (WCRP)

In 2013, Future Earth was initiated as a global research platform supported by the Science and Technology Alliance for Global Sustainability (comprising the International Council for Science [ICSU], the International Social Science Council [ISSC], the Belmont Forum, the Sustainable Development Solutions Network [SDSN], the United Nations Educational, Scientific and Cultural Organization [UNESCO], the United Nations Environmental Programme [UNEP], and the World Meteorological Organization).

Future Earth promotes interdisciplinary research across a broad range of fields such as natural science, social science, engineering, humanities, and law, including co-design and co-productions with stakeholders from different sectors (research, science-policy interface, funders, governments, development organizations, business and industry, civil society, and media). Future Earth's Secretariat consists of five international and four regional hubs and has five functions: coordination, enabling research, communication and outreach, capacity building, and synthesis and foresights. The Regional Center for Future Earth in Asia was established at

RIHN.

The Future Earth 2025 Vision has been published and three research themes, including Dynamic Planet, Global Development, and Transformation toward Sustainability. The W-E-F Nexus represents one of the eight challenges. There are 23 ongoing core projects under the Future Earth framework; they focus on water, Earth system governance (ESG), climate change, and food security, among others.

Figure 3. Screenshot of the homepage for the Regional Centre for Future Earth in Asia.

In March 2016, the Science Council of Japan identified five themes for Japan to address within Future Earth: the W—E-F Nexus, biodiversity, urban-rural interactions, sustainable technology and institutions, and natural disasters.

Figure 4. Schematic of Submarine Groundwater Discharge (SGD) (courtesy of the RIHN W-E-F- Nexus project).

Introduction of the RIHN Nexus Project

Dr. Aiko Endo introduced the RIHN Nexus project in the Pacific Ocean Ring of Fire. The purpose of RIHN Nexus project is to design optimal policy and to increase human-environmental security within the complexity of the W-E-F Nexus system. Dr. Endo emphasised that advancements in Nexus research will develop more explicit linkages between terrestrial and marine systems, on the basis of the hypothesis that the flow of nutrients from land to ocean affects the coastal ecosystem. This suggests that water use for producing or consuming food or energy on land might affect fisheries production in coastal areas. Dr. Endo explained that the project design consists of the following five groups: the water-energy nexus group; the water-food nexus group; the site-specific stakeholder analysis group; the science in/for society group; and the interdisciplinary group.

Next, Dr. Endo introduced the project timeline. During the initial stage, trade-offs and conflicts for each research site were identified. Two primary objectives were set, namely: a) to understand the complexity of the W-E-F Nexus system; and b) to propose policy options to solve the identified nexus problems with scientific evidence and under scientific uncertainty. The project is now in the developmental stage and its focus is therefore more on objective B. Subsequently, the water-energy nexus and water-food nexus groups will continue to pursue objective A, while science in/for society, stakeholder analysis, and interdisciplinary groups will continue to engage in objective B.

Dr. Endo highlighted the project's achievements in the fiscal year 2015 as follows: The water-energy nexus group analysed effective potential energy production using water; examined changes in river ecosystems caused by the changes in heat environments; and studies to support diversification among renewable energy sources. The water-food nexus group examined the interlinkages between groundwater and fishery production. To address objective B, the stakeholder analysis group identified W-E-F Nexus stakeholders and their interests. Stakeholder meetings and individual interviews were used to clarify differences in the public's attitude toward energy production. The science in/for society group studied the cultural significance of wells and springs in local communities and households and the interdisciplinary group developed integrated methods for interdisciplinary and transdisciplinary research approaches.

Dr. Endo ended her presentation by summarising future directions of the projects from the perspective of different spatial and temporal scales.

Discussion

The discussion indicated that less emphasis has been placed on energy in the Strategic Research Agenda (SRA) and no energy function has been defined in Japan's Global Environmental Change (GEC) platform. Furthermore, there is no strong collaboration with energy-related stakeholders and it remains challenging to involve or attract more energy-related stakeholders in the Nexus project.

Panels

Panel 1: Understanding the Complexity of the Water-Energy-Food Nexus System

The Food-Energy-Water Nexus in Taiwan

Yu-Pin Lin of National Taiwan University and Tsair-Fuh Lin of National Cheng-Kung University described the Food-Energy-Water (F-E-W) Nexus in Taiwan. The most important components of the F-E-W Nexus in Taiwan are electricity, crop production, and water resources (domestic use, industrial use, and irrigation). In Taiwan, F-E-W Nexus activities involve studies to identify significantly correlated factors and the development and launch of new projects. Topics being addressed by Taiwanese research include land resources, ecosystem services, water resources management, urban and environmental changes, coastal changes, climate change and adaptation, and a multidisciplinary research project on F-E-W Nexus Security in the context of urbanization.

Taiwan is an island with an area of 36,000 km^2, with many mountains (covering 60% of the island) and diverse vegetation. It has a population of approximately 8.73 million and a GDP per capita of USD $22,317. In 1971, 25% of the island was under cultivation. This area had decreased to 22% in 2008. Primary energy consumption has been increasing but at a slower rate since 2005. 49% of energy is consumed in the form of electricity. Most of this power comes from petroleum and coal products (80%); other sources include nuclear (16.3%), renewables (3.8%), and hydraulic power (1.2%). Imports of fossil fuels, raw materials, and products account for 12.6% of the GDP.

The rain that falls on Taiwan is partitioned into evaporation (21%), runoff (74%), and groundwater infiltration (5%), ratios that are characteristic of country with a humid environment. Water consumption totals 17.6 billion gallons per year (72% agriculture, 19%

domestic, and 9% industrial). Urbanisation, globalisation, and industrialisation are creating impacts, risks, and opportunities for F-E-W Nexus components. In particular, electricity use increased by 22%, with 200% growth in the transportation sector and a 34% increase in the industrial sector from 2003 to 2013. Crop production has decreased by a small amount but increased in some counties.

Increases in population and the growth of the industrial sector are responsible for the increasing demand for electricity. While crop production has undergone only small changes, irrigation water use has fluctuated due to the water rationing policy during drought, when irrigation water is transferred for residential and industrial use. Domestic water consumption decreased, presumably due to incentive programmes for water conservation, while increases in industrial output were correlated with increases in electricity consumption, although they did not have a significant impact on industrial water use.

Ongoing globalisation, urbanisation, industrialisation, and climate and environmental change will continue to put pressure on water, food, and energy security. Renewable energy sources will be needed to provide a safe, effective, sustainable, and clean energy supply. A multidisciplinary framework is needed to ensure that co-benefits and trade-offs of the F-E-W Nexus and its security are derived from research and are incorporated into improved management. International collaborations related to the F-E-W Nexus should promote transferable and scalable approaches and solutions.

In his talk on the Nexus of complexity, sustainability, and solutions, Dr. Dennis Ojima of Colorado State University argued that the F-E-W Nexus should be considered a system-of-systems. He noted that the Nexus, for example, involves a people, culture, and social-ecological systems nexus that differs geographically and by spatial scale. To address these interactions, we need solutions that integrate bottom-up and top-down collaboration and minimize the effects of bad trade-offs. It is important to find the Nexus's leverage points to enable good actions and outcomes. The Nexus needs to be defined in terms of system linkages, sustainability dimensions, action foci, and multi-scaled and multi-criteria actions and actors. System linkages in the F-E-W Nexus must consider sustainability processes (dimensions: people, environment, and economics nexus); action foci (people and research policy nexus); and scale (global, regional, and local).

Sustainability: People, Research, and Policy

Onanong Tapanapunnitikul of the Center for Advanced Studies on Agriculture and Food in the Greater Mekong Subregion (CASAF-GMS) at Kasetsart University gave a talk on the sustainability of the W-E-F Nexus. He gave the example of community-based approaches to W-E-F management using sustainable glutinous rice community development in the Mekong sub-region. More than 50% of the world's glutinous rice is produced in the ASEAN region. The world market is 6,530 germplasm: Laos uses 2,470 germplasm, Thailand 1,289 germplasm, and Viet Nam 273 germplasm.

Most farmers produce glutinous rice for household consumption, but 15% of farmers cannot grow enough to satisfy their own household needs. Furthermore, 51% of these farmers earn no income from growing this type of rice. In part, this occurs because the average farm is only

1.91 hectares per family. On average, glutinous rice farmers earn less than 10% the amount that other rice farmers earn. On land used for glutinous rice, only 9% of the area is irrigated regularly and another 4% has irrigation equipment installed but is irregularly used. This community has adopted a sufficiency economic philosophy, which holds that knowledge and integrity must feed into a middle path marked by reasonableness, moderation, and immunity that enables progress in a balanced, stable, and sustainable way. Details on this new approach for managing land and water can be found at http://www.leafninjas.ca/blog/week-rak-tamachat/.

Dr. Jiaguo Qi of the Center for Global Change and Earth Observations at Michigan State University gave a talk on the complexity of the W-E-F system in Asia. There are large variations in predicted climate change and its impacts across Southeast Asia, including Asia Pacific hotspots. Dr. Qi introduced the topic by showing graphs outlining how climate change could affect water, energy, and food by 2025. Some factors that make the W-E-F Nexus in Asia unique are monsoon systems, which dominate the regional climate; the Himalaya Mountains, which act as water towers; dense population and social diversity; agriculture, aquaculture, and livestock traditions; significant economic disparity; the interconnectedness of systems on different scales; population pressures; economies in transition; and a lack of interest in traditional knowledge. In addition, the ASEAN area will experience increasing climatic variability by 2050.

The Lower Mekong region represents a complex W-E-F system where rural livelihoods increasingly face food, water, and energy challenges resulting from climate change and disruptive water resource developments such as hydropower competition (see SavetheMekong.org). According to the International Energy Agency (IEA), the demand for energy will grow by as much as 37% by 2040, with rising consumption centres in Asia, Africa, the Middle East, and Latin America. By 2030, China will need to expand 1.5 times the current U.S. level for energy and India will need the total power generation of Japan, South Korea, and Australia combined (IEA).

The demand for food (and meat) is growing. To meet forecast global growth in demand for food over the next 20 years, farmers will need to increase agricultural production by 70% to 100%. More than 25% of this increase in grain demand will actually be due to changes in consumer diets (meat).

UN Water has shown that the key drivers impacting water are all external to the “water box.” We must act in a coordinated way to address these problems. The same is true for the food and energy sectors. No one can solve these problems individually because they are too tightly interconnected.

Dr. Qui concluded that we need to address the requirement of balancing food, energy, water, and livelihoods by understanding the consequences of increasing monsoon variability and extreme climate events; collaborating across sector, scale, and borders for the national and regional sustainability of Asian systems; increasing the role and understanding of traditional knowledge; assessing trade-offs because they are critical priority research used to balance long- and short-term needs; and assessing the dietary changes that drive W-E-F Nexus complexity.

Integrated modelling systems linking the W-E-F Nexus for trade-off analyses must include effective observations, system models, socioeconomic components, telecoupling, and R^3 (ridge, river, and reef): mountains, river/land, and ocean linkages are missing from the modelling system.

Dr. Shinji Kaneko of Hiroshima University presented a comparison of the Water-Energy-Carbon Nexus in three Asian cities. He noted that water and energy are usually managed as separate entities even though they are fundamental to many other economic sectors. While water, energy, and carbon are complex, their relationships must be identified and quantified, especially in cities in which their nexus contributes to GHG emissions.

Energy use is growing due to increasing demands for water. In turn, increased energy production leads to greater water requirements. Dr. Kaneko's current research project is based on the hypothesis that in an urban context, energy for water provision is more significant than water for energy production. Furthermore, changes in the energy footprint have implications for the carbon footprint. Quantifying energy and water footprints provides guidance on ways to optimise systems. The urban water and wastewater sectors were assessed for three cities in Dr. Kaneko's study. The Bangkok Metropolitan Region, which covers 7,761.5 km^2 and has a population of 10.5 million; Tokyo, which covers 2,188.0 km^2 and has a population of 13 million; and Delhi (National Capital Territory), which covers 1,486 km^2 and has a population of 16.7 million.

In Bangkok, since 1982, water has been drawn from the Chao Phraya and Mae Kong Rivers because groundwater extraction is prohibited. Energy intensity for water abstraction is 0.009 kWh/m^3. Bangkok has four water treatment plants (WTPs) that leave an energy footprint of 0.047 kWh/m^3. The energy footprint for moving water in Bangkok is 0.081 kWh/m^3. Bangkok also has 7 WTPs whose energy footprints range from 0.09 kWh/m^3 to 0.2 kWh/m^3. Bangkok's WTPs tend to have large pumps for collecting wastewater.

In Delhi, water is taken from the Yamuna and Ganga Rivers and groundwater. Energy Intensity (EI) for water abstraction is 0.3 kWh/m^3. EI is higher in Delhi than Tokyo or Bangkok due to the abstraction of groundwater. As groundwater levels decrease, the energy used for pumping increases. Delhi also has 10 WTPs with an energy footprint of 0.17 kWh/m^3. In Delhi, water is moved by pipelines (energy footprint of 0.5 kWh/m^3) and tankers (energy footprint of 526.3 MWh/d). There are 13 WTPs in Delhi whose average energy footprint is 0.11 kWh/m^3.

In Tokyo, water comes from the Edogawa, Tonegawa, Tamagawa, and Sagamigawa Rivers and a small amount comes from confined groundwater aquifers. The EI for water abstraction is 0.19 kWh/m^3. Tokyo has 11 WTPs whose energy footprint is 0.29 kWh/m^3. Tokyo has higher treatment standards, more energy-intensive technologies, and transfers water by pipeline over long distances. The energy footprint for moving water is 0.13 kWh/m^3. Tokyo has 13 WTPs whose energy footprints vary from 0.19 kWh/m^3 to 1.1 kWh/m^3. The higher energy footprint reflects Tokyo's policy of treating water to a higher standard. In some Tokyo treatment facilities, resources and energy are even recovered from the treatment process.

Overall energy footprints in Bangkok's water and wastewater sectors are 0.21 kWh/m^3 to 0.25 kWh/m^3 for water and 0.09 kWh/m^3 to 0.2 kWh/m^3 for wastewater; in Delhi, 0.9 kwh/m^3 for piped water, 526.3 MWh/d for tankers for water supply, and 0.11 kWh/m^3 for wastewater; and in Tokyo, 0.23 kWh/m^3 to 0.60 kWh/m^3 for water and 0.15 kWh/m^3 to 0.24 kWh/m^3 for wastewater.

Table 1.

	Water Treatment Technologies	Supply Systems	Wastewater Treatment Technologies	Water and Sludge Reuse	Energy and Carbon Implications
Bangkok	Rapid/slow sand filtration Advanced water treatment	Piped networks	Activated sludge system	No reuse	High carbon footprints
New Delhi	Rapid/slow sand filtration Membrane filtration in new systems RO and UV filters are used in end-use side	Piped networks and tankers	Activated sludge New system includes membrane bioreactor	High energy Carbon footprints due to use of fossil fuels	High energy Carbon footprints due to use of fossil fuels
Tokyo	Rapid/slow sand filtration Partially advanced water treatment Membrane filtration	Piped networks	Activated sludge system Semi-advanced/ advanced wastewater process	Use of reclaimed water and recovery of energy from wastewater by-products	High energy Carbon footprints Comparatively best management practices

The study indicates that the urban Water-Energy-Carbon Nexus is important for direct and indirect perspectives on water and energy use in this environment. The urban water cycle's energy and carbon footprint depends on characteristics that include the nature of water sources, distances, the nature and extent of infrastructure, the choice of technologies, losses, and management practices. A better understanding of drivers and quantification of the energy and carbon footprint is needed. Energy security, climate change mitigation, and water security are three key contemporary policy issues that must be integrated and whose solutions must be optimised locally. The urban Water-Energy-Carbon Nexus is a key area to study in order to support urban planners.

The panel discussion at the end of the session introduced several factors associated with complexity. In particular, the role of boundaries was discussed. One perspective held that there are no boundaries for W-E-F Nexus processes because trade means that events in one country affect countries around the world. For example, the market for soybeans in China has led to deforestation in Brazil. Counter-examples show that boundaries between countries are significant because adjacent countries may have different educational levels, prosperity levels, and agricultural, energy, and water use policies, among many other differences. Boundaries often depend on perceptions and the effects of boundaries are difficult to quantify or even predict.

The issue of uncertainty and risk was discussed. Risk is important because it can stimulate more responses from farmers than opportunity. Risk is also important in the context of climate change and even seasonal forecasts. Risk must be considered in the evaluation of adaptation options. Within the W-E-F Nexus study, we need to address risk in a systematic way by looking at all factors: climate, consumer demand, and economics, among others. The interactions of these factors can multiply their effects on risk. Risk is at the heart of W-E-F Nexus security since the whole activity addresses factors that will influence sustainability. Given the complexity of risk, we should consider integrated risk (all three sectors are considered together) and trade-offs addressing all of the concerns should form the basis of the analysis. Uncertainty was also discussed in the context of decision-making. More accurate forecasts with less uncertainty have the potential to benefit decision-making.

Other discussion questions related to the economic needs of sustenance farmers such as glutinous rice for off-farm income. Another concern was raised regarding the lack of energy data because private-sector energy companies often do not make their data available to support analysis.

Panel 2: Approaches on Different Spatial (Vertical and Horizontal Dimensions) and Temporal Scales (e.g., GEO, Telecommunication, Future Scenario)

Dr. Ailikun of the Chinese Academy of Sciences discussed regional climate scenarios produced by the Joint Coordinated Regional Downscaling EXperiment (CORDEX) activity in Asia. Outputs from these models could be very helpful in addressing W-E-F Nexus issues. Within WCRP and GEWEX, CORDEX attempts to produce consistent actionable regional information that includes regional models, data-sharing, and capacity building. Outputs include past, present, and future (predictions and projections) maps with quantified uncertainty that can be based on assessments and validations. The model is generally run at resolutions of 50 km by 50 km, although higher resolution products (25 km by 25 km) are produced for some domains. A total of 26 models are being run for the project with the support the Asian Pacific Network (APN). In the project’s second phase, additional domains have been added in the southeast, over Asia and in East Asia.

The CORDEX Asia Data Supporting Frame includes nodes and data-sharing protocols between nodes. In addition, it has an implication for the end users’ framework that involves key institutes and organizations in assessment research related to hydrology, agriculture, ecosystems, land cover/use change, and human health. CORDEX Asia Training engages core Asian institutes and organizations. The Core Statistical Downscaling group workshop will be held in the Philippines in July 2016.

The next steps for CORDEX Asia include simulations at 25 km for southern Asia, some higher-resolution products in specific regions, additional Earth System Grid Federation (ESGF) nodes in Asia to establish links between the CORDEX Asia statistical downscaling group with end-users' groups, and improved capacity building using topic-focused training. More interaction among institutes, development organizations, and other stakeholders in CORDEX Asia will be encouraged.

Dr. Catherine Downy of ESA presented an overview of satellite Earth observations and the W-E-F Nexus from an ESA perspective. She noted that ESA's Earth Observations strategy for society includes the global challenges of water, energy, and food. The W-E-F Nexus issue is suited to the application of information from the new Sentinel operational missions and, in some cases, from the Earth Explorer scientific missions. Sentinel satellite series include Sentinel 1a, 1b, 2a, and 2b, which have a predetermined distance between each other so that they can observe a width of 290 km with a resolution of 10 metres and cover all areas in 5 days.

Relevant datasets and potential products from these satellites for W-E-F Nexus studies can be identified. Water products include: water quality, watershed use change, snow and glacier monitoring, wetlands monitoring, water reservoir mapping, irrigation water management, aquifer monitoring, precipitation, soil moisture, and evapotranspiration. Food and agricultural products include land use and land use change maps, crop location and type mapping, crop acreage mapping, early warning indicators, yield assessment, precision agriculture, land degradation, clear cut and burnt area maps, soil moisture, ocean colour, and sea surface temperature (SST) (for fisheries). Energy products include: geological mapping, habitat assessment maps, logistic planning support, mine waste monitoring, illicit mining detection, renewable resources mapping and monitoring (solar, wind, wave, tidal, and hydropower), and crop yield estimates for biofuels, among others. However, to date, no products have been specifically developed for the W-E-F Nexus by ESA because they are waiting for the W-E-F Nexus community to develop and communicate the needs in specific terms.

Other variables such as climate change datasets were also discussed. Dr. Downy outlined a strategy for making EO data more useful for the W-E-F Nexus by providing better access to data and analysis tools; developing techniques and platforms to ensure scale compatibility; ensuring the continuation of data collection and data services; improving data quality (trust in data); adopting standardised formats; improving metadata definitions; and making adequate data available for its intended use.

The ESA Science Strategy will provide free and open data access policies for Earth observations. Thematic Exploitation Platforms generally address data for specific users' needs that exploit developments in technology and computing. Current themes include coastal, forestry, hydrology, polar, urban, and geohazards. Cloud computing is used to rapidly process and analyze large amounts of data.

To make EO data more useful for W-E-F Nexus studies, ESA is ready to address issues such as data quality, standardized formats, and better metadata. In this regard, ESA would like to see the needs of the W-E-F Nexus framed in terms that the space agencies can address (such as the Essential Climate Variables). Opportunities for engaging in ESA activities can come through ConnectinGEO, which facilitates the use of essential variables in GEO Societal Benefit Areas (via the H2020 program, which includes water, energy, and agriculture). The community is also invited to explore the Thematic Exploitation Platforms (tep.eo.esa.int) and Copernicus Services (www.copernicus.eu/ConnectinGEO).

Toru Miyama of the Japan Agency for Marine-Earth Science and Technology described the value of addressing ocean phenomena on different scales as part of an effort to understand the role of the spatial scale in managing fisheries in the Sukumo Bay. The Sukumo Bay is a concern because fish catches are decreasing. In this study, undertaken by the Japan Coastal Ocean Predictability Experiment (JCOPE), Chlorophyll-a derived from TERRA/MODIS was used to demonstrate the influence of Kuroshio Sea Surface Temperature on ocean productivity. These temperatures affect productivity in the Sukumo Bay, one of the richest ecosystems in Japan. The Bay also supports active aquafarming and many popular marine resorts (e.g., fishing, diving). The study involves the development of an ocean analysis and a forecast system for the Sukumo Bay in which nested models are used to represent multi-scale phenomena. Each model hierarchy is being co-built and co-designed with stakeholders appropriate to the specific scale. The JCOPE modelling system focuses on Kuroshio prediction (JCOPE2) and coastal predictions and their application to fisheries, ship routing, ocean energy, and the Ocean Forecast System. The nested system includes Kuroshio prediction at 9 km, coastal prediction (JCOPE-T) at 3 km, and Sukumo Bay prediction (JCOPE-Sukumo500) at 200 m.

After capacity building and with the right management and tools, local communities have contributed to the development of diverse datasets, including topography, streamflow, and data on catches from fishermen. In addition, data linkages have been made with Kuroshio Oyashio Watch and the new Sustainability Initiative in the Marginal Seas of South and East Asia (SIMSEA) project. In summary, multi-scale objective ocean diagnosis can help with the comprehensive management of coastal zones and nested models can allow us to handle multi-scale phenomena.

Dr. Charles Vörösmarty, Director of CUNY's Environmental CrossRoads Group, summarized scaling lessons for the Nexus domain based on African water resources and Arctic domain studies. The Africa study analysed contemporary populations under high water stress (demand/supply greater than 40%) based on grid-based (30° latitude and longitude) estimates that captured spatial variability within countries. Lessons from the African study include the recognition that there are practical limits to how much increased resolution information can help provide an accurate picture of water stress and the need to develop river corridor perspectives. Time resolutions are also important for understanding the impacts of specific events.

Dr. Vörösmarty also provided an overview of the U.S. Arctic Research Commission's discussion of scaling issues as they affect national policy, priorities, and goals for basic and applied scientific research on the Arctic. The Arctic study featured interactions with diverse constituencies (Arctic residents, local institutions, U.S. and international Arctic researchers and research organizations) to promote a broad view of Arctic research needs. The Commission recently addressed the importance of scale in understanding Arctic system processes and contributing to strategic application issues in order to identify gaps and opportunities for federally funded research. These studies addressed complex data streams at multiple scales and assessed the connection between physical, biological, and human systems. They concluded that Arctic systems are subject to tipping points, feedbacks, and linkages from Arctic teleconnections in the larger Earth system. In addition, scale effects differ across disciplines. There are clear implications for interdisciplinary research and assessments.

Based on these studies, Dr. Vörösmarty concluded that:

1) Scaling issues and even the definitions of scale are so varied across individual disciplines that they hinder interdisciplinary research.
2) Scale incongruities among components give rise to opportunities to study intermediate scales.
3) Thresholds are scale-sensitive and important, yet prove difficult to detect, study, and/or predict.
4) Scales of human perception are much different than those associated with the study of natural systems.
5) Information has not been well structured to facilitate cross-scale studies.
6) Scientific conclusions and uncertainties require better translation into information for policymakers.

Well-focused, mission-oriented questions and objectives help self-define scale issues and could be an important way forward for the W-E-F Nexus. In addition, forums on scale are needed for an interchange among scientists, policymakers, and managers on the issue of uncertainty and how to interpret and use these estimates in a proactive and positive manner.

Richard Lawford of Morgan State University and NASA introduced NASA assets that support the W-E-F Nexus. He introduced an observational strategy for the W-E-F Nexus that addresses the GEOSS Water Strategy Essential Water Variables (EWVs), noting the different existing and anticipated sources for different types of data.

Specific W-E-F Nexus-related variables that are regularly mapped using data from NASA missions and sensors include precipitation (rain and snow) from the Global Precipitation Measurement (GPM); vegetation, land surface temperature, and evapotranspiration from MODIS and Landsat; soil moisture from the Soil Moisture and Ocean Salinity (SMOS) (ESA) and Soil Moisture Active Passive (SMAP) missions; and variations in groundwater from the Gravity Recovery and Climate Experiment (GRACE) satellite data used in conjunction with a land surface model. Other planned moisture missions include the Surface Water Ocean Topography (SWOT) mission, which will measure stream discharge and surface water height, two variables that are currently only available through in-situ measurements.

NASA supports GEOGLAM, a global collaborative initiative that facilitates transparent decision-making related to agriculture by making data available on continuously changing global agricultural conditions. It supports integrated global and regional systems and the main producer countries for wheat, corn, rice, and soybeans. Based on these successes, NASA is working with NOAA and USGS to develop the GEO Global Water Sustainability (GEOGLOWS) initiative to address similar issues in the area of water security and sustainability. The framework for GEOGLOWS is shown in Figure 5.

Working with USAID, NASA has installed a number of regional SERVIR nodes to distribute remotely sensed data and products in developing regions. Four of these nodes have been installed (Panama, Kenya, Nepal, and Viet Nam) and a fifth is now being installed in Ghana, West Africa.

NASA maintains data services that support W-E-F Nexus research and management by providing data and data products through archival centres in the U.S. and elsewhere. Space-based observations supplement in-situ ground-based observations of W-E-F Nexus-related variables. NASA’s policy of free and open data access has expanded the use of data from its current and future missions.

In summary, existing systems could be brought together for the needs of the W-E-F Nexus, in-situ studies are essential but space-based information is an essential supplement, and free and open data access has led to the expansion of data usage and users, thereby generating more demand and large returns of investments on the mid- and long term.

GEO Global Water Sustainability (GEOGLOWS)		
1. Global Water Security Enhancement	**2. Minimizing Basin and Regional Risk**	**3. Essential Water Variable (EWV) Understanding**
Sustainable Development Goals	Integrated Water Prediction	Water Quality
Water Scarcity and Access	Floods	Water Use
Climate Change	Droughts	Water Cycle Variables (Precipitation, Soil Moisture, Groundwater, Evapotranspiration, Stream Flow, Surface Water Storage [incudes Snow Pack])
Cold Regions	Land Use	
Ecosystems and Biodiversity	Transboundary Issues (IWRM)	
	Water-Energy-Food-Environment-Health Nexus Climate Change Adaptation	
4. Earth Observations, Integrated Data Products and Applications, and Tool Development **5. Data Sharing and Dissemination of Data, Information, Products, and Knowledge** **6. User Engagement, Capacity Building, and AmeriGEOSS**		

Figure 5. Draft GEOGLOWS structure.

The concluding panel discussion dealt with issues of user involvement and the specification of scale for applications, the role of scale in interdisciplinary research and in Earth observation programmes, and issues related to data availability and accuracy when many types of data are involved. The importance of understanding the linkages between scale, data (or model output), and uncertainty was noted. For example, regional projects often require high-resolution datasets. This problem is best addressed by reducing uncertainties and working with users so that they understand data limitations.

Interdisciplinary research poses communication problems and gives rise to issues related to scale compatibility when exchanging data. Clear, well-articulated questions within an interdisciplinary framework are an excellent basis for establishing mutually agreed upon nomenclature, analyses frameworks, and quantification of descriptors at appropriate scales. Space agencies address scale issues by understanding user needs and maximizing the resolutions available from the sensors and satellites that they can afford to put in space. When different data sources are included, such as fisheries statistics, some data providers may be reluctant to fully share their data (or to share it for free) because they recognize the implications that the release of these data could have for the resource base (for example, fishermen will heavily fish in those areas that are reported to be productive, thus removing the fish from the production cycle).

Panel 3: Water-Food Nexus from the Perspective of Fisheries, Livestock, and Waste

Dr. Ching-Cheng Chang introduced the Asia-Pacific Economic Cooperation (APEC) multi-year project "Strengthening Public-Private Partnership to Reduce Food Losses in the Supply Chain" (2013-2016). The purposes of the project are to: identify key issues on reducing food loss and waste; seek best practices in the private and public sectors; and find practical solutions and enhance capacity-building. Dr. Chang detailed the project's knowledge-sharing activities and achievements, such as seminars held from 2013 to 2015. In addition, she showed the project's loss assessment methodologies, including the commodity system analysis (CSA) and the mass flow model (MFM). Dr. Chang explained the progress of data collection and sharing activities in 12 countries.

Dr. Chang also identified the major challenges for the capture fishery and aquaculture supply chains, solutions taken in New Zealand and Japan, and next steps for database construction and public-private partnership (PPT) from the W-E-F Nexus perspective.

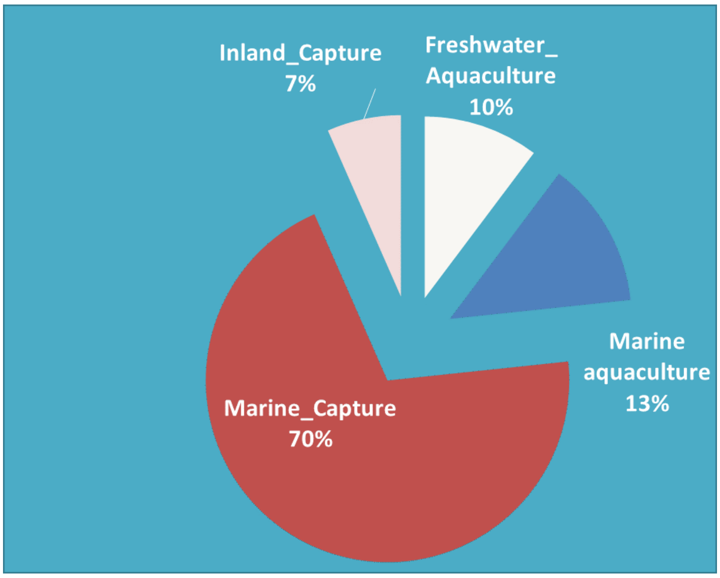

Figure 6. The ocean in food (presented by Dr. Chang).

Dr. Qinxue Wang presented a study on the W-E-F Nexus for climate change adaptation strategies in Mongolia based on the Joint Credit Mechanism (JCM). The purposes of the study are to work on developing a Water-Energy-Food Nexus model to evaluate both CO_2 emissions by energy use and CO_2 sequestration by ecosystem enhancements and to identify the effects of low carbon technologies, mitigation, and adaptation strategies. Dr. Wang introduced the Early Warning Observation Network for capacity building, which is funded by the Japanese Ministry of Environment. He explained the use of the permafrost index (PMI) to detect the degradation of permafrost and the water deficit index (WDI) to identify land-surface moisture conditions. He also created a Bio Geochemical Cycles (BIOME-BGC) model to estimate the Net Primary Production (NPP). The study found that before the 1990s, the actual livestock number was lower than carrying capacity; since 2000, however, the livestock number has been much higher than carrying capacity. The researchers also simulated the Active Layer Depth (ALD) of permafrost under five scenarios using the Simultaneous Heat and Water (SHAW) model. Results showed that both drought and overgrazing would accelerate the degradation of permafrost and would result in the degradation of grassland production. Dr. Wang concluded that global warming would cause the degradation of permafrost, which would then lead to land-surface water deficits and desertification, followed by the decrease of CO_2 sequestration. In addition, the CO_2 sequestration by vegetation in Mongolia decreased since the 1960s, especially from 1980 to 2010 due to both climate change (warming and drought) and livestock overgrazing.

Next, Dr. Wang showed that CO_2 emissions from fossil-fuel burning in Mongolia increased significantly since the 1980s. Moreover, CO_2 concentration measured by GOSAT showed an apparent increasing tendency even in these several years. Dr. Wang concluded by showing the Nexus-based proposals for adaptation strategies, which consist of climate change adaptation strategies such as remote area well allocation, livestock number control based on carrying capacity, and renewable energy technologies.

Dr. Masahiko Fujii, the water-energy group leader for the RIHN Nexus project, described the current energy situation in Japan. Japan’s self-sufficiency ratio for energy is about 5%. The installation of renewable energy facilities has been accelerated after the Fukushima Nuclear Power Plant Disaster in March 2011 and the Feed-in Tariff (FIT) system, which began in July 2012. Dr. Fujii reviewed possible conflicts in enhancing renewable energy and promotion in baseload renewable energy. For example, in Otsuchi, a town affected by a tsunami in 2011, potential electricity generated by five small hydropower plants was calculated. It was about 2,000 MWh after excluding low head sites and forest areas and sites far from roads in which it is difficult to install and manage small hydropower facilities, and taking riverine ecosystems such as salmon, trout, and brisling into consideration. This may cover 4% of total demand in Otsuchi and may reduce CO_2 emissions to 2,026 t-CO_2.

Dr. Fujii introduced recent experiments in Beppu, a hot spring resort area in Japan. Changes in the heat environment caused by drainage water from hot spring resorts and hot spring power generation affect river ecosystems. Hot spring drainage creates a more suitable habitat for Nile Tilapia, a foreign species. If new power generation facilities increase the amount of hot spring drainage, other rivers may show similar environmental conditions as in the Hirata River. Dr. Fujii concluded by identifying current issues and next steps needed for the water- and foodfriendly installation of baseload renewable energy. These include local stakeholder analyses and capacity building.

Dr. Jun Shoji, a water-food group leader for the RIHN Nexus project, presented on fish species diversity and production around submarine groundwater seepage. In comparison with the international trends of nexus projects, the advancements in RIHN nexus research will develop more explicit linkages between terrestrial and marine systems. This is because fisheries activities are essential for providing animal protein to the Japanese and other Asian populations. A primary challenge of the RIHN Nexus project is to analyse the interlinkages between groundwater and fisheries production. This is in line with the hypothesis that the flow of nutrients from land to ocean affects the coastal ecosystem: water used for producing or consuming food or energy on land might affect fisheries production in coastal areas. Specifically, changes in SGDrates cause changes in nutrient flux, resulting in changes in primary production, which in turn lead to changes in fishery resources. Greater fish abundance was observed at areas with more SGD. In addition, there was a positive correlation between primary production and radon concentration, as a groundwater tracer of SGD in Wakasa Bay. Dr. Shoji showed how the thermal effects of groundwater affected fish production and how heat from groundwater affects fishery production.

Dr. Osamu Tominaga, a member of the RIHN Nexus project, introduced the contribution of SGD to fisheries resource production using stable isotope (SI) signature as a hydrological tracer to clarify the origin of water. The contribution of SGD to fisheries resource production has not yet been scientifically verified. The SI value of each chemical element indicates the contribution rates of SGD. Dr. Tominaga used the Manila Clam (*Ruditapes philippinarum*) as an SI indicator. He conducted a field rearing experiment at six sites under different SGD conditions in the Obama Bay. He showed that there is a positive correlation between ^{222}Rn and dissolved inorganic nitrogen (DIN); a significant positive correlation between ^{222}Rn and primary production; that the δ13C $_{SHELL}$ shows some possibility of being a proxy for environmental reconstitutions of submarine groundwater discharge; and that it is necessary to account for other environmental conditions (water temperature, wave strength) when evaluating the growth of bivalves.

There was a lively discussion about ocean systems following the panel. For example, it was noted that seawater temperature and ocean acidification are influenced by climate change. Dr. Fujii, an oceanographer, explained that climate change affects coastal ecosystems, including corals and fisheries migration. For instance, sub-tropical fish can be seen in Kochi, which belongs to the temperate zone. Global warming also raises ocean temperatures and ocean acidification affects fisheries production. Furthermore, heat waves caused by global warming damage livestock and vegetation, which will in turn increase fish consumption.

Tuesday, April 5, 2016

Panel 4: Methods of Water-Energy-Food Nexus for interdisciplinary and transdisciplinary research

Dr. Aiko Endo, Session Chair, introduced the following questions for the panelists:

1. What are the pros and cons of using your methods to address Nexus issues?
2. What is new in your methods to address Nexus issues? Is it developing the functions of existing methods, or developing new methods?
3. When and how can you use your methods effectively to conduct interdisciplinary and transdisciplinary research?
4. How can you use your methods to address Nexus issues from the perspective of temporal and spatial scales?

Dr. Anik Bhaduri introduced the various representations of the W-E-F Nexus and SWFP's role in advancing W-E-F Nexus understanding. He explained that advances take place through the integration of scientific and practical knowledge and a demand-driven innovation process. Dr. Bhaduri also explained the four types of capital (financial, natural, human, physical, and social) used to evaluate human well-being from the Nexus perspective. Next, he demonstrated "nexus cubes" that represent water, energy, and food security. He concluded that most countries currently would have smaller cubes and that a bigger nexus cube needs to be achieved, all the while minimizing the cost to the environment (see Figure 7). In closing, Dr. Bhaduri briefly introduced the SWFP Water Solution Lab Network, which has the following roles:

1. Address the broad SDGs agenda.
2. Achieve multiple objectives simultaneously.
3. Connect science to policy-makers.
4. Benefit private small and medium enterprises.
5. Reduce transaction costs and increase confidence and transparency.

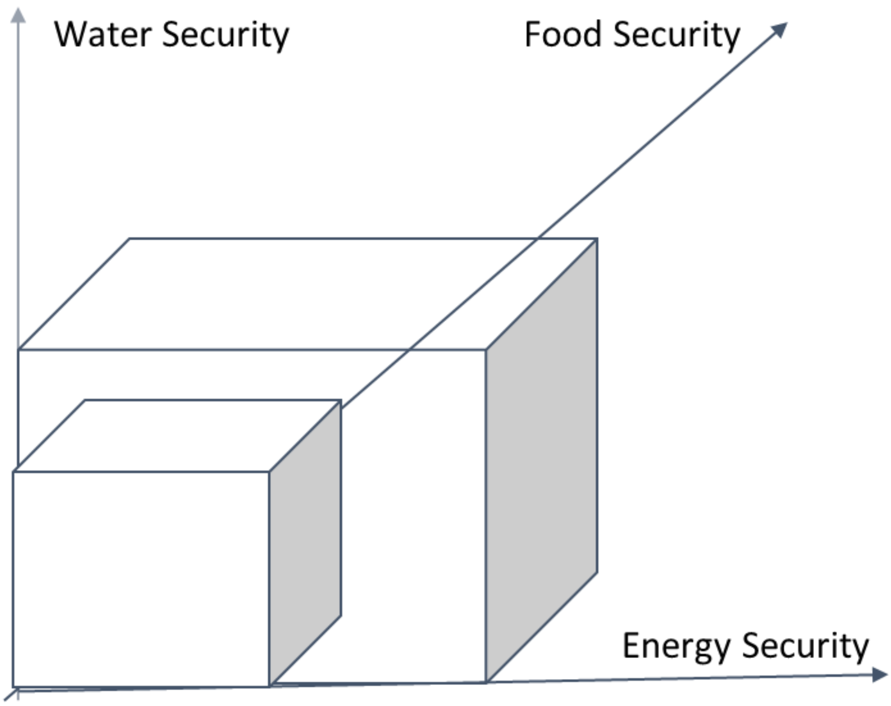

Figure 7. Schematic of Nexus cubes (courtesy of Griffith University).

Dr. Chad Higgins hypothesised that "social systems adopt a 'nexus ethic' that shifts consumptive patterns to more sustainable levels" (based Professor E. O. Wilson's "search for a new environmental ethic"). Dr. Higgins spoke about making Nexus decisions and the building blocks of a W-E-F Nexus framework. As shown in Figure 8, the Nexus system helps us understand resource interactions for four components (biophysics, natural resource, improved quality and availability, and end use) and the utility of water, energy, and food resources (biochemistry, ecosystem and climate, policy and management, and population and economy). Dr. Higgins concluded that the W-E-F Nexus is a system that transforms and transports natural resources to meet the demands of the population. It can be represented in a single differential equation, as follows:

$$\frac{\partial r_r}{\partial t} = \mathbf{A}_{r_{st}} r + \mathbf{R} d_r$$

transformations distributions

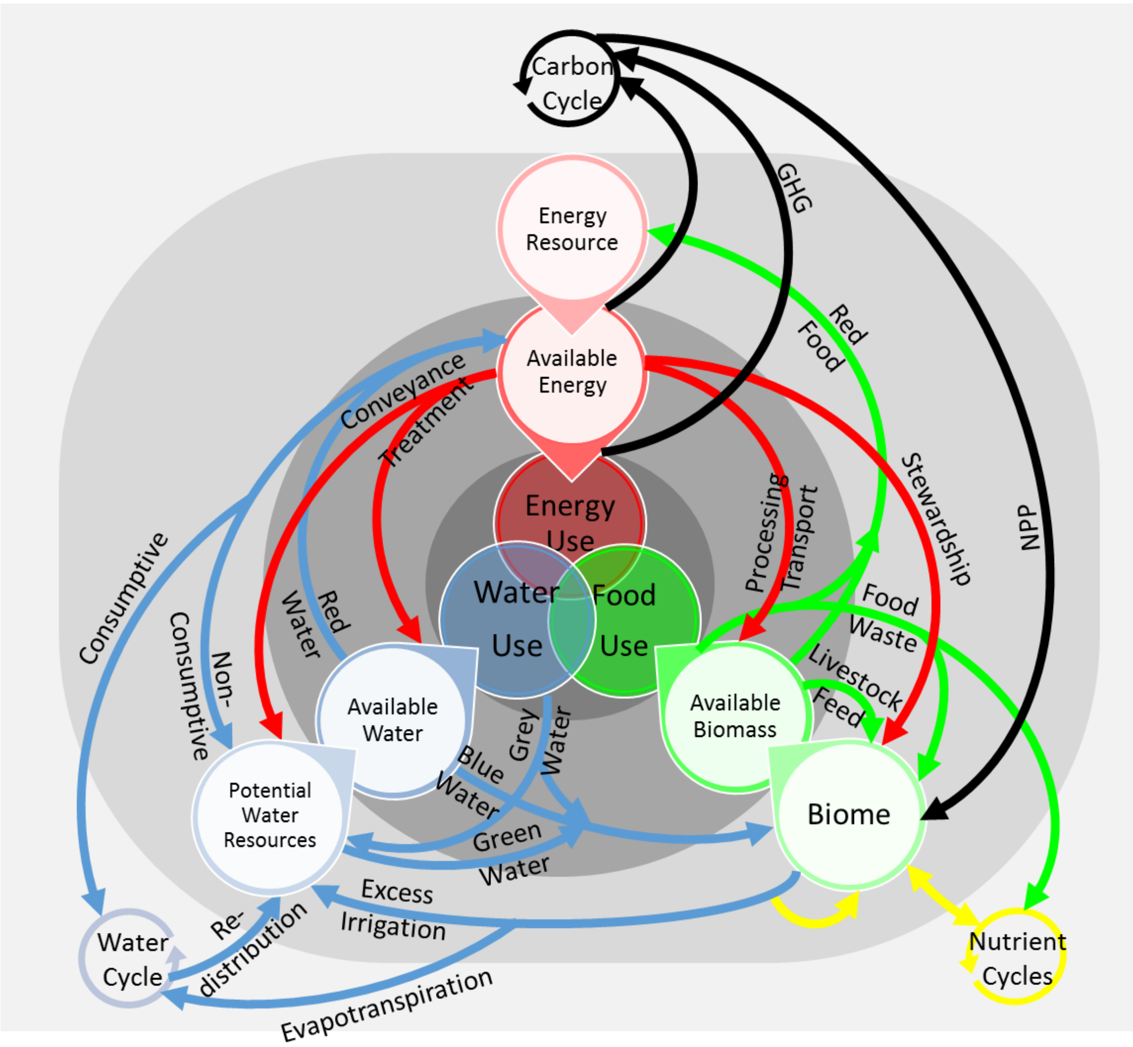

Figure 8. The W-E-F Nexus system presented by Dr. Higgins.

Dr. Higgins also proposed that future Nexus practices need to reach consensus, create community nexus models (or protocols to integrate existing models), include a centralised depository of resource transformation and transportation; consist of a grassroots effort to fill in the depository; and transition from nexus perspectives to a nexus approach.

Dr. Hong Yang presented on China’s biofuel production from the perspective of the water and land footprint. She outlined biofuel development in China between 2004 and 2015 and showed that since bioethanol has become commercially available in 2004, biodiesel production has remained very small compared with bioethanol. Biofuel’s main feedstocks are maize, sugarcane, and sugar beet. In addition, Dr. Yang mapped maize distribution and the locations of large maize-based bioethanol plants, sugarcane production, sugar beet production, cassava, and sweet sorghum.

Dr. Yang also presented the Environmental Policy Integrated Climate crop model, which simulates crop growth by considering different factors such as climate, soil, land use, crop type, irrigation, nutrients, and other management factors. She concluded that in order to achieve its biofuel production target by 2020, the Chinese government will require 6 million to 12.4 million hectares of land based on an assessment of land and water footprints. Furthermore Dr. Yang explained that the average commercial rate of grain production in China was about 50% and that 4% of maize production for biofuel would translate to an approximate 8% reduction in maize supply in the market for food and feed.

Dr. Pedcris Orencio of the RIHN Nexus project introduced the integrated indices and indicators that are being developed following the case study in Calamba and Los Banos in the Philippines. The purposes of the indices are to evaluate human environmental security from the water-food nexus perspective and to improve interdisciplinary research. Dr. Orencio explained the process of creating indices and selecting indicators by considering different spatial scales (such as local to national) (see Figure 9). One of the indices’ most outstanding characteristics is its evaluation of security by determining the threshold for severity such as access to sufficient and good quality water for economic and household use. Dr. Orencio discussed some of the integrated indices based on the 460 samples collected using a questionnaire in nine barangays in Calamba and Los Banos in March 2015. Based on these surveys, he evaluated water and food security using four indicators: availability, access, utilisation, and management.

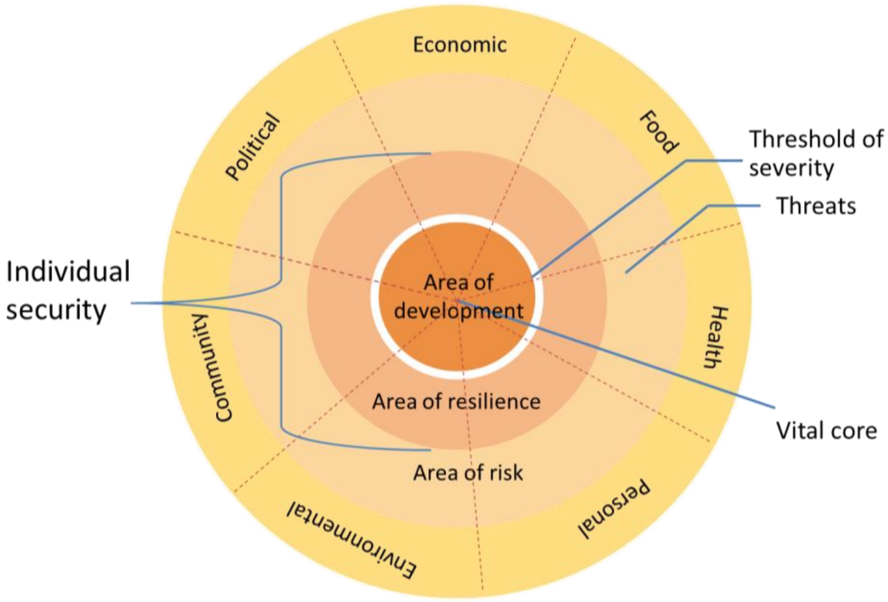

Figure 9. Individual security presented Dr. Orencio.

Dr. Fi-John Chang presented a new W-E-F Nexus project on intelligent system dynamics in the context of urbanisation in Taiwan. He also described subprojects related to urban system dynamics modelling, including the ecological footprint; life cycle assessment to analyse dynamic changes in food production; planning the most suitable sustainability production areas; estimating energy consumption and analysing energy efficiency; and optimising the water allocation system under urbanisation using Artificial Intelligence (AI) technology, system dynamics, and self-organising maps.

Dr. Chang compared W-E-F Nexus management in urbanised and non-urbanised basins to evaluate the impact of urbanisation on the Nexus. The scalability and transferability of methods was taken into consideration during modelling and platform construction. Dr. Chang explained that his project identifies Nexus indicators using an Artificial Neural Network; builds a novel intelligent interactive platform for synergy-based resources allocation in the Nexus; uses AI techniques to optimise benefits and target indicators through cross-sectoral resource allocation; and designs scenarios in response to possible future conditions of the W-E-F Nexus. In closing, Dr. Chang suggested transboundary cooperation for W-E-F Nexus issues focusing on regional situations, such as Japan’s high urbanisation rate, Viet Nam’s subtropical climate, and Australia’s green economy.

The session ended with a discussion of W-E-F Nexus research methods. The following options were presented:

1. Combine engineering and biological approaches in the form of a generalised differential equation.
2. Develop integrated indices/models and site-specific, problem-oriented research to provide solutions to stakeholders.
3. Upscale site-specific results.
4. Identify the need for basic research or a proper W-E-F Nexus discipline.

Panel 5: Governance in the W-E-F Nexus (institutional arrangement, legislation, policy, capacity, development, stakeholder involvement)

After introductory comments by the session chair, Dr. Kenshi Baba of Tokyo City University presented a case study on Beppu, Japan to illustrate participatory approaches for co-design and co-production of outputs related to the W-E-F Nexus issue. Dr. Baba introduced the question "How safe is safe enough?" to imply a framing gap between experts (scientific evidence) and the public (local knowledge), which results in uncertainty and mistrust. Trust is essential in integrating the different kinds of knowledge and therefore it is essential for experts and public stakeholders to be in dialogue in the early stages of problem-definition and agenda-setting. Co-design and co-production also foster capacity among stakeholders and prevent too many false alarms in the relationship between the public and scientists. In the first step of an ideal participatory process, suitable scientists, experts, and stakeholders single out technical and/or comprehensive issues. In the second step, community-specific issues are dealt with by a broader public; for example, through scenarios. In the third step, action plans are developed collaboratively. This participatory approach was used in the W-E-F Nexus projects undertaken in Obama, Beppu, and Otsuchi.

Beppu is famous for its hot springs, with approximately 8 million visitors a year and three 100 kW-200 kW geothermal steam power stations. In the business model of the Goto-en geothermal power station, different actors came together to fund and operate the station through a special purpose company. The possible conflict between increasing the use of hot springs for energy purposes versus leisure tourism required a participatory process to identify acceptable solutions in this trade-off. Forty stakeholders representing different groups took part in interviews. As a result, there were no obvious disputes over the hot spring resources but, with new construction, conflicts may arise and the binary use of geothermal energy and hot spring should be planned. Co-design and co-production helped identify knowledge gaps, misconceptions, and research demands and reduced stakeholders' perception that the project was high-risk.

Dr. Masayo Hasegawa of the International Environment and Economy Institute introduced Future Earth's engagement principles and practices. The vision is for people to thrive in a sustainable and equitable world by generating new knowledge through international research coordination and by catalysing transformation through a solutions agenda and greater societal engagement. This shall be achieved by uniting around a common research agenda for global sustainability science; engaging societies in new ways; and creating high-quality research, products, and networks that support transformation. Defining engagement is a central part of Future Earth's vision. It means new ways of organising and creating opportunities for excellence and science in society. There are four principles for engagement by Future Earth:

1. Engagement should be proactive.
2. Engagement needs to be flexible.
3. Engagement approaches must recognise and address potential tensions and vested interests.
4. Engagement approaches need to be inclusive and transparent.

The strategy for engagement in practice includes a platform called the Future Earth Open Network, strategic dialogues, raising public awareness, making best practices accessible, and developing co-design capacity.

Dr. Zaw Naing of Mandalay Technology highlighted the importance of water for agriculture in Myanmar. Until now, 61% of the work force in Myanmar was employed in agriculture, producing 37% of the GDP, and hydropower is the main source of electricity with a growing demand and an increasing investment in the sector. The environmental and societal impacts of hydropower development in Myanmar can already be felt. Floods and drought occur in Myanmar and the economy depends on climatic variations. Natural disasters like cyclone Nargis (2008, 150,000 casualties, 2.4 million people affected) are a big issue and threaten the livelihood and security of the population. Many different disaster risk reduction and management activities were carried out by several actors and stakeholders; for example, on geospatial and satellite information. In July 2015, many parts of Myanmar were affected by heavy flooding. The emergency response was already better than the response in 2008 and involved many different stakeholders on all levels. International cooperation mechanisms provided satellite data and geo-information (Sentinel Asia, for instance) but disaster preparedness was insufficient. There remains a need for a national agency or centre for disaster preparedness, improved coordination between international and UN organizations with Myanmar stakeholders, gathering national baseline information and imagery in a database, sustainable land use development planning, community-based disaster management planning, and capacity building by Myanmar's universities, especially using GIS. Overall, achieving these goals requires communication, cooperation, coordination, and collaboration among the different actors and scales.

Dr. Tony Shih-Hsun Hsu of National Taiwan University presented on the General Equilibrium Model for Taiwan Economy and Environment (GEMTEE) model for W-E-F Nexus analysis in Taiwan. An input-output table of the economy was used to show the connections among stakeholders, identify income inequality, and illustrates the emergence of trade-offs between the agricultural and other sectors over water, especially during a drought. The purpose of the three-year project, funded by the Academica Sinica and the Australian Bureau of Agriculture, Resources and Science, was to construct the dynamic, computerised GEMTEE, which treats the process of population ageing and physical capital investment endogenously. Farm household income was an important indicator because approximately 80% of Taiwanese household income is derived from off-farm income due to commercialisation, industrialisation, urbanisation, and globalisation. The urban influence is important because agriculture is just one of several sectors of the economy and household members generate income from other sectors, especially if they live closer to urban areas. Nonetheless, there is still farmland in between high-rise buildings in urban areas. Rural development is not equal to agricultural development and food self-sufficiency is not equal to food security. Land prices are increasing but the value of farm land is determined by agricultural output, not urban factors.

Dr. Claudia Pahl-Wostl of the University of Osnabrück presented on governance challenges of the W-E-F Nexus. Governance failures cause problems for W-E-F Nexus security: inappropriate governance settings, lack of respect for good governance principles, a lack of implementation of governance arrangements, and a focus on technical, natural science approaches. There is also a failure to acknowledge “messy” problems with low consensus and high uncertainty when it comes to factual knowledge, values, and goals. Will more evidence lead to better governance and, if so, under which conditions? The north-western area of Germany, where high livestock production resulted in a groundwater problem and posed a coordination challenge for the W-E-F Nexus, served as a case study. Groundwater resource management had been approached from a multi-level governance perspective, resulting at first in improved water quality but, with the implementation of a federal law on renewable energy in 2000 and the resulting increase of land under maize cultivation for bio-energy, water quality decreased again from about 2006 onwards. Additionally, the price of land changed dramatically. The case study shows that the abundance of data does not prevent coordination failures, Developments could have been foreseen and better coordination across the Nexus at the level of policy development is needed. Flexibility to coordinate across the Nexus during policy implementation is essential, and a broad and inclusive deliberation on targets to be achieved and how this should be accomplished is required. Coordination could be supported by legal prescriptions, monetary evaluation of trade-offs, building networks (the W-E-F Nexus as a new narrative), supporting boundary organizations, and combining governance modes. The process of governance reform and transformative change should be emphasized, not idealized outcomes. It takes a multilevel perspective for transformative change and that requires effective links between informal settings and formal policy processes, polycentric structures with flexible, effective coordination, and continuity. Change takes decades to years.

Breakout Groups

Breakout Group No. 1: Observations and Science

Richard Lawford introduced the breakout session, noting that the goal is to identify actions that should be taken to ensure observations and information systems that are relevant to the needs of the W-E-F Nexus are developed.

Do some W-E-F Nexus science questions transcend demand-driven innovation? If so, what are they and how can they be addressed?

Transcendent issues that require basic science include research on thresholds, boundaries, and intersections of W-E-F Nexus elements. Studies of market strategies and broader interactions between consumption, production, and environmental distortions (inadvertent consequences) are also needed. The data available for these studies need to be enhanced: for example, there are requirements for more relevant observations, access to private-sector data, chemical by-products of W-E-F Nexus processes, etc.

Typologies and lexicons with unified definitions of terms for the W-E-F Nexus need to be developed to facilitate communications. One way to test these lexicons and databases is to take a specific problem and assess whether all of the terms needed to address the problem are clearly understood by all sides and whether the databases are available to address the problem. For example, a specific project (such as dam construction) could be reviewed to ensure we are collecting the appropriate data. These assessments should emphasize scale compatibility, completeness, and uncertainties. Within the broader W-E-F Nexus context, testbeds (like the Mekong River Basin) and use cases (communal farming) should be undertaken to show how the use of information can be optimized and supported by good governance.

We should support the SDG indicators to enrich our databases and secure our observation systems for the W-E-F Nexus.

How could W-E-F Nexus science questions and information be structured to allow the benefits of observations and models to be maximised?

This discussion led to several unanswered questions: Is there sufficient data to determine the policy gap between supply and demand issues within the W-E-F Nexus cluster and to project these into the future? Is there a multi-problem question that we could use to create a "new wave" of model innovation in order to consider more than one aspect of the Nexus? Projecting future energy and food demand and supply is easier than water demand and supply. Water is influenced by different variables. We need measurement tools to obtain the data for water inventories to assess how much water flows into a basin, for example. Prediction is challenging because predictions are needed for different time scales. The capability to make decisions under uncertainty is needed. Thresholds, feedbacks, and unintended consequences also need to be considered (salinity, groundwater intrusion, and methodologies on measuring human aspects). We need spatially resolved data on consumption and production (e.g., using smart sensors) to make general meaningful assessments.

What data on the interactions between the water, energy, and food sectors are needed to help characterise the Nexus?

Concern was expressed that without a more specific problem, answering this question would result in a long catalogue of variables without clear direction. However it was recognized that we need to understand the information gaps to assess the value of inventories of different data types. Some of the variables needed include high-resolution water table depth as a function of topography. Access to utility companies' data would be an asset, but we must first address privacy issues and information ownership. National economic account statistics organised as national input-output tables can provide some useful broad-scale information. Estimates are needed for quantities of water that are involved in interactions in comparison to the volumetric amounts required for basic processes (e.g., by-products of the effects of thermal pollution).

Multi-scale data representations are important. For this reason, the discussion focused on the attributes of the required data. The impact of polluted water on food production quality is also important. Questions about the effects of wastewater recycling for food production, the effects of water and energy markets on the transformation processes of food production, and company policies and advocacy regarding the impacts of the individual long-term sustainability at the expense of the environment must be addressed. We should support green development (economic growth), safety, utilities, and services. Standardising terminology for the Water-Energy Nexus would be useful (for example, shale gas extraction resulting in water losses, possible water loses from hydropower production, changes in the environmental quality due to production processes). As noted earlier it would be useful to develop a Nexus typology or categorisation system so that we all use the same definitions. We should ensure these definitions are consistent for different uses of water in different parts of the world (e.g., augmentation of services, consumptive water use, and water withdrawals).

Which variables are essential for managing the W-E-F Nexus?

The data needs for the variables involved in the W-E-F-Nexus subsets would constitute a long list. For example, if we consider dam construction and other major transformations of river systems, our data requirements would include information on the structures, their operations, impacts on biodiversity, withdrawals from water storage, and effects on the W-E-F Nexus. Other factors include the effects of upstream flows into reservoirs and siltation and sediment trapping of coastal deltas. Coastal areas can subside, requiring large investments to maintain infrastructure. Volumetric changes of water, rivers, and lakes will lead to sediment build-up and trapping, flows, and the signature of water and inventories of coastal wetlands. New habitats for lake-based protein sources need to be mapped. Assessing the impacts of new city development on the W-E-F Nexus will lead to different categories or packages of observations. Impacts may be assessed by using the typology approach as the basis of the observational programme. New suites of information that would support the SDGs include carbon (food circulation), nitrogen measurements (coal, animal discharge, soil ecosystems), the water system, energy prices, food prices, and their long- and short-term fluctuations. The data inventories being developed for the SDGs may address some of these problems.

How can Earth observations and integrated models enable assessments across sectors for the W-E-F Nexus?

Using a W-E-F Nexus model such as the Higgins model (see Fig. 7) indicates that 35 variables need to be available to represent Nexus interactions. Inventories exist for many of the variables. Engineering systems can be accurately defined and specified but social and natural systems have uncertainties. Effective integrated models for the W-E-F Nexus, particularly for social systems, do not exist. Furthermore, there are mismatches among scales of models and their observations. Options for assessing these mismatches include case studies, inter-scale studies, observational modelling system analyses, and test beds that allow for model development and calibration. Integrated assessments through simplified models can be carried out. Issues to be addressed include designing for solutions; data formatting; data sources (cloud computing and remote sensing data); and the integration of technologies. If the Belmont Forum is considering data sharing as part of an e-infrastructure call, we could explore opportunities.

Are current observations at the proper scale and frequency to meet the needs of the W-E-F Nexus?

Trade-offs are needed to balance the effects of clouds on an eight-day interval for Landsat observations. MODIS provides more frequent observations but the resolution is not as good. Countries need a focus for developing inventories and data and motivation for sharing these resources. Surface water information on storage, irrigation, and inundation are needed. A clear problem statement and an associated research objective are needed for developing observational strategies, defining the specific observations needed, and identifying their time and space resolution. For example, bio-fuels should consider an area with a low water footprint and should be presented at the provincial or basin level. It should be noted that maintaining long-term observations to develop a baseline will continue to be difficult.

How can social, economic, and physical data be integrated into a common analysis framework for W-E-F Nexus issues?

Scenario-based assessments can be explored and use-case scenarios may be useful. The Mekong River Basin holds opportunities for a further case study. Science and user perspectives are difficult for co-design. Trade-offs, synergies, and cross-scale approaches are relevant.

Breakout Group No. 2: Governance and Management

The objectives of this breakout group were reviewed by Dr. Claudia Pahl-Wostl, who chaired the group discussions.

What are the major governance challenges for sustainably managing and enhancing security in the W-E-F Nexus?

In order to define a research programme for the W-E-F Nexus, there is the need to obtain a consensus-based definition of the Nexus. This precision is needed to define who the stakeholders are and to assess the current institutional arrangements (avoiding policy differences). A process is needed to define the transformative steps to effect change. Different policy regulations, including subsidies targeted toward one sector, need to be defined in the W-E-F Nexus context. Governance requirements in times of high and average economic growth must be considered (trade-off between priorities in quickly growing economies). There is a lack of societal/political debates about goals on all levels. Other gaps include policy integration (vertical integration covering the whole W-E-F Nexus), the absence of institutional arrangements (sectoral government), and the lack of a space for integration, interaction, and negotiation. To facilitate the mainstreaming of the Nexus we need good, easily understandable indicators to share with the general public, increase transparency, and promote trust in government. An integrated approach to the W-E-F Nexus needs to be adopted and communicated by institutions. Clear purpose and objectives are often missing regarding coordination and networking by institutions. Institutions can change if they see the real benefits. In this context, institutions can involve rules and ministries, so change can be very slow. Laws take decades to be prepared and to be put into force, especially in Europe. People tend to restrict discussion to currently existing ministries and mandates, so joint plans don't have formal meanings, nor can they be easily related to new structures. Better knowledge can help reduce the time period for adopting new opportunities.

Should W-E-F Nexus governance focus on security as target and thus on risk governance?

There was discussion of the pros and cons of the word *security* to reduce sectoral thinking, although the term may be less warmly received at the national level in some countries. Asking what could be practically achieved by using the word *security* poses several different challenges. It could be a valuable way to achieve some governance structure for operationalising the concept. The definition of security and W-E-F Nexus security is elemental and the indicators for defining it should be developed. In the water field, there is a shift, with water security being at the centre. If the W-E-F Nexus guides this discussion, we should measure and monitor what we want to achieve. Security at the global level is clearer, but on a national level policy makers' focus is on national concerns and, possibly in some cases, on military pressures. They may not consider the needs of adjacent countries, which is a priority element for the W-E-F Nexus. For example, the European programme on food security and climate change includes consideration of the contributions of neighbouring countries by showing that the focus is on human-oriented security. Using the term *security* may cause some people to think of water, food, and energy separately. Security would have to be used for the global context, just like Earth system security considers intersectoral interactions (e.g., the dyke being built at the Japanese coast to secure human life is destroying the ecosystem). Water security means providing acceptable services for livelihoods, for the economy, for people, and for the environment at a tolerable level of risk (where "tolerable risk" needs to be defined). For example, China has an export tax on rice for food security purposes. More international trade can enhance food security but may not be seen as a national security issue. Based on behavioural theory, people would tend to secure things within the perimeters of their control. Resilience means the ability to respond to disturbance. Resilience is not static and should not be interpreted as returning to the original status. The advantage for the W-E-F Nexus is that it addresses multiple sectors. It might not be suited to transformations, as they are proactive, while resilience seems to be more reactive. Measuring resilience is difficult and policy supporting resilience can be difficult to develop. *Sustainable* may be more meaningful than *resilience*. Sustainably consuming goods and services derived from resources means not decreasing them.

At which level could and should the W-E-F Nexus be governed and how can levels be better integrated (vertical coordination)?

Governance at the national level seems rather fixed; consequently, the local or supranational levels may provide more opportunities for experimenting with governance approaches. Scepticism about countries being ready to coordinate W-E-F Nexus activities on a regional or supranational level was expressed. It was agreed that the level for assessing governance strategies should be selected on the basis of the level that generates the most interest. The regional/supranational level in Asia is still open and new innovations could be introduced. The embedded interests are not always clear. On the other hand, the local level could be more flexible as changing national or larger scales would be very difficult. The Stiglitz report on the well-being of households described the W-E-F Nexus but summed up contributions from the household level to the national level, which gives a different result than focusing just on the national scale. The links between national and household levels need to be better understood. APEC has a food security forum that might be place for the W-E-F-Nexus. Watersheds don't reflect the governance scale of energy or food. There is a tendency to build dams for hydropower and later find that they severely impacted aquatic ecosystems. Often national policies meant to boost large-scale farming do not benefit small-scale farmers. The W-E-F-Nexus cannot solve all these issues around the social-environmental dimensions: there is a need for vertical coordination.

How can effective and meaningful indicators be developed?

A score card system for Nexus governance at the national level could be developed. It should go beyond the MDGs by selecting objective indicators rather than indicators designed to make governments look good. It could reflect policies that currently support the W-E-F Nexus and the extent to which W-E-F security was achieved. To make the assessment meaningful, people, businesses, and municipalities have to be involved. Monitoring should engage local communities. Perhaps a pilot country could be chosen for developing and evaluating the methodology. Scorecards are diagnostic but don't necessarily lead to progress. National indicators for sustainability are available but are not used for management purposes. The indicators have to be locally meaningful but still must be comparable over different areas. Participatory indicator development and co-design is important. One view was that countries need their own indicators, along with decision making processes and policies that will encourage them to respond to these indicators. Choosing indicators can be difficult. Different indicators are often promoted by different scientists. In Taiwan, there are sustainable development indicators on the national, provincial, and community levels and it is difficult to make decisions based on those coming from the national development council. At the national level, there is a requirement in many countries to use the existing indicators, so having more indicators would just make monitoring more difficult. However, indicators tend to only be used when the debates arise. Scientists should become more active in the debates. Environmental indicators are not sufficiently linked from the household to the national level. The OECD education indicators are debated at all levels. The indicators must be co-designed. In some cases, indicators may not be used because they are too technical. Getting the salmon back into the Rhine was an indicator to mobilise the public but it had little impact. Participatory development helps create indicators. Indicators need transdisciplinarity; however, some remain sceptical that policy makers would endorse such indicators because the indicators would be more visibly accountable.

What are promising instruments to support sectoral (including marine fisheries) coordination of the W-E-F Nexus?

Periodical dialogue among stakeholders is important. Science is a useful platform for getting people together and overcoming barriers. An inventory of the potential successes and failures of policy instruments would be helpful. Instruments should be created based on co-design and co-production. Long-term coordination beyond the project's lifespan is necessary. However, going beyond existing mandates is currently not being rewarded.

How can W-E-F Nexus governance profit from different information sources and knowledge (Earth observations, local knowledge)?

The Solution Lab being launched by SWFP seems like a promising way to combine knowledge and develop innovative solutions. It could act as a training platform for practitioners. With the new European Sentinel satellites, there is a whole industry developing applications (e.g., apps for farmers).

What steps are needed to expand the scope of energy discussion in this project? On which issues should these discussions focus?

To engage energy specialists more in the W-E-F Nexus initiative, we should identify the most appropriate stakeholders in each project. In general, stakeholder engagement should be enhanced in the process of developing the W-E-F Nexus action plan. Future Earth engagement principles should be used to guide better stakeholder engagement. There is a need for more institutional support and co-design to involve all stakeholders in developing dialogues. Funding agency policies therefore need to be changed.

Wednesday, April 6, 2016

Panel 6: Formulating networks with Future Earth Nexus KAN and SDGs

Dr. Sandrine Paillard of the National Centre for Scientific Research summarized the eight focal challenges defined in Future Earth's 2014 strategic agenda. The eight challenges are part of the Future Earth 2025 Vision:

1. Water, energy, and food for all.
2. Decarbonise socioeconomic systems AND adapt.
3. Safeguard natural assets.
4. Build healthy, resilient cities.
5. Sustainable rural futures.
6. Improve human health under GEC.
7. Sustainable consumption and production.
8. Social resilience to future threats.

In order to approach these challenges, Future Earth's governing body decided in November 2015 to launch eight knowledge action networks (KAN). The collaborative frameworks are meant to facilitate highly integrative research. The main goal is to build new knowledge through collaborative identification of issues and by synthesising existing knowledge. The KANs build on Future Earth's 21 core projects, fast track initiatives, and clusters and on organisations, projects, and individuals that are part of Future Earth's open network. This network will become a large, open, and vibrant community using the latest digital technology. This technology, currently in beta-testing, will allow its members to engage with one another, share ideas, build relationships, catalyse projects, and discuss global sustainability science. While individual projects deal with specific questions, the KAN provides a broader overview of the research related to societal demand. The KAN will be more integrative and has the possibility to reach out, making it more relevant for practitioners and policy-makers. For the W-E-F Nexus, the initial challenge is how to better manage interactions between systems to deliver water, energy, and food for all. The focus is important to ensure a link is built to the SDGs. The scoping phase (2016-17) has four main goals: constitute the Nexus KAN open network and development team, support the preparation of proposals to relevant calls, conduct an agenda-setting reflection and spread its outputs, and develop a research and engagement plan. The purpose is to facilitate the preparation of proposals and to focus on the agenda-setting reflection. The development team regularly holds meetings and its outputs are discussed and enriched by the wider network, resulting in the KAN research and engagement plan.

Dr. Ojima provided an overview of the SDGs and global action. Several activities relating to the W-E-F Nexus exist within the international science-policy interface. The 17 SDGs provide a framework and there are the three obvious connections of the W-E-F Nexus with SDGs 2, 6, and 7. The goals are highly linked among each other and shall be approached in an integrated way with system-level action, as strategies are developed for joint actions within and across nations. Food system and food security approaches will have to integrate across multiple goals and include social-ecological system perspectives. GEO approved its 2030 agenda for sustainable development in September 2015. The SDGs are the anchor for their agenda because they assist countries and the global community to measure, manage, and monitor progress on economic, social, and environmental sustainability. The 2030 agenda specifically demands new data acquisition and integration approaches to improve data quality, coverage, and availability in order to support the implementation of the development agenda at all levels. In order to support KANs across the different projects from observation to information, the data systems information task force has been set up and should work with the KAN. The Sustainable Development Solutions Network has formed a group with leading modelling teams to perform an integrated assessment that addresses the full spectrum of SDG challenges for the world in 2050. Other on-going assessments include IPCC, IPBES, GEA, CSA, the Vulnerability Impacts Adaptation Climate Services Advisory Board (VIACS), the Global Land Project, the Global Carbon Project, Earth system governance, and the international nitrogen initiative.

Dr. Norichika Kanie of Keio University reviewed Earth system governance, SDGs, the Knowledge Action Network, and integrated approaches for the SDGs. In anticipation of the SDGs, the Earth System Governance Project released a number of publications resulted from challenging transdisciplinary processes. A co-design workshop consisting of researchers, UN officers, and state representatives was held in February 2014. Its results were conceptualised and a policy proposal was developed. Similarly, a science-policy interface workshop was held in June 2015. Participants included academics and stakeholders (government representatives, UN officials, NGOs, etc.). The workshop provided input into the negotiating text through government representatives and proposed a new form of science-policy interface. Partly in response to these inputs, the SDGs were crafted under a new governance strategy because it started with aspirations and the setting of goals by nations and was then later formulated into an international regime. The Future Earth initiative was initiated at the Rio+20 conference in 2012. Future Earth plans to play a role in the process of developing and implementing SDGs and promote the delivery and uptake of policy-relevant knowledge. The SDGs are a more nested concept, not the classical sustainability pillars, and therefore have different implication strategies for policy and implementation. This leads to challenges in creating national-level SDGs and implementing mechanisms and processes to engage stakeholders. Some countries will try to prioritise the SDGs within their own national priorities and will set up complementary indicators accordingly. Developing countries seem to be doing better at this because of their experience with the Millennium Development Goals. The relevant Future Earth KANs could get involved in these challenges and in the cross-cutting issue of capacity building through windows of opportunity such as the Global Sustainable Development Report. It is an official mechanism to enhance the science-policy interface published every year. Three case studies have already been undertaken (Japan, the Netherlands, and Sweden), showing that the integrated approach and the mere extension of the existing policies is not sufficient to achieve the 2030 targets. The SDGs could become a tool for reconsidering existing national policies in terms of long-term and global standards. It can also be used as a checklist to create a more coherent agenda by considering interlinkages in the policy agenda. Lastly, it could be utilised for exporting good policy practices to other countries through multi-stakeholder forums on science and technology and innovation for the SDGs and/or HLPF.

Dr. Tetsuzo Yasunari of RIHN described Future Earth's eight focal challenges and how they go along well with the 17 SDGs. To deliver water, energy, and food for all is the first one. The W-E-F Nexus KAN is being connected with five of the other seven KANs and although they overlap at times due to the geographic separation of urban and rural areas, they nevertheless require different perspectives and will develop on their own. Discussions on the initial streams of activities have been held and the initial development team is being formed. The team will include members from the core projects, science committees, and external partners. The urban nexus will be launched by the end of 2016. By the second quarter of 2017, the scoping process for the initial activity streams will be completed and by the third quarter the funding will have been received for a series of research proposals on the Nexus in urban contexts. The Implementation Strategy is being created now and will be published very soon.

Questions related to the integration of the interests at regional and trans-national levels within this structure remains to be discussed, In Asia, links could be developed through multilateral organisations such as ASEAN or APEC. These links could be valuable for regional offices in addition to the national and international institutions.

Summary Session

Summary Discussion of Proposals:

Dr. Vörösmarty proposed a follow-on initiative including a pilot project to explore stresses in the W-E-F Nexus using appropriate geospatial data. The project would involve developing and testing a version 1.0 WEF Integrated Typology-Data Compendium-Analysis framework that would focus on an analysis of stresses in the W-E-F Nexus in order to facilitate and enable the development of a common working nomenclature to be developed and early hypothesis testing. The project would demonstrate the value of using a broad spectrum of data resources (e.g., synoptic space-borne to high-resolution in-situ biogeophysical data, social and economic information, etc.). The analytical framework would serve as a testbed to identify opportunities and address data gaps. The availability of the system could stimulate multi-scale analysis (from global to regional, sub-regional, and place-based); quantitative "dialogue space" for stakeholders (e.g., SDG support), and baseline data and capabilities upon which operationalisation could be built.

To show the types of analysis that can be done with geospatial data, Dr. Vörösmarty presented several case studies that have been carried out in the past and could serve as a basis for future analysis. One example of a big dataset was the database used to generate the Global Water System Project Atlas. Dr. Vörösmarty suggested the development of a W-E-F Nexus data/information atlas based on a similar concept. He suggested identifying and creating maps of main elements of the W-E-F Nexus to illustrate which W-E-F Nexus-related problem(s) exist(s) and creating a set of categorised and colour-coded maps using threshold values to identify W-E-F Nexus issue hotspots. Success stories could be mapped and interventions could be evaluated to see which had positive impacts on a particular scale.

As a basis for this approach, Dr. Vörösmarty presented the U.S. Northeast Hydro-synthesis Project results to identify spatial hotspots (most important areas) with respect to desertification, population, reservoirs, nutrient flow, etc. To study W-E-F Nexus issues, we could use existing datasets (provided people/data providers are willing to share data). Dr. Vörösmarty proposed undertaking a prototype study in next six months, subject to the availability of funds and personnel.

In the discussion that followed, questions were raised about data sources from different disciplines needed to carry out the analysis; about the steps that should be undertaken to "operationalise" this research project; and about funding sources. Dr Bhaduri discussed various sources of funding that could sponsor this project and future research.

Session: Workshop Summary

Dr. Pahl-Wostl, who chaired the concluding session, introduced the next steps of collaborative W-E-F Nexus research. In particular, she elaborated possibilities for linking Nexus research to SGD targets and goals (specifically with links among Water, Climate Change, Hunger, and Energy SGDs).

The discussions addressed:

- Launch a W-E-F Nexus case study in the Mekong River Basin.
- Develop the final report to the Future Earth W-E-F Nexus Cluster activity.
- Discussion paper on the W-E-F Nexus (based on workshop discussions and including expert input).
- Develop a workshop report outline to have maximum impact on Future Earth research.
- Discuss the need to link global W-E-F Nexus studies with the SDGs.

Dr. Pahl-Wostl asked for inputs from the participants on the achievements of the workshop and its synthesis. She also made suggestions for organising future workshops.

It was recommended that the proposal to develop prototype assessment tools for analysing W-E-F Nexus-related problems be adopted and further developed. (ACTION: Dr. Charles Vörösmarty.)

As part of the follow-up to this workshop, the slides and notes will be collected for use in the preparation of the final report to SWFP and possibly posted on the new SWFP website. Participants were asked to review their slides and send a revised set if they are concerned about copyright issues. (ACTION: All.)

Dr. Pahl-Wostl thanked participants on behalf of the organising committee and thanked RIHN staff, making special mention of Dr. Aiko Endo, who worked so hard to arrange the facilities and the programme. Speaking on behalf of the host institution, Dr. Endo closed the workshop and expressed her gratitude to all the workshop participants for attending.

Appendix A

Acronyms

AI	Artificial Intelligence
ALD	Active Layer Depth
APEC	Asia-Pacific Economic Cooperation
APN	Asian Pacific Network
ASEAN	Association of Southeast Asian Nations
BIOME-BGC	Bio Geochemical Cycles model
CASAF-GMS	Center for Advanced Studies on Agriculture and Food in the Greater Mekong Subregion
CORDEX	Joint Coordinated Regional Downscaling EXperiment
CSA	Commodity system analysis
DIN	dissolved inorganic nitrogen
DIVERSITAS	International Programme on Biodiversity Science
EI	Energy intensity
ESA	European Space Agency
ESG	Earth system governance
ESGF	Earth System Grid Federation
ECV	Essential Climate Variables
EWV	Essential Water Variables
FAO	Food and Agriculture Organization of the United Nations
FIT	Feed-in Tariff system
GEA	Green Energy and Green Economy Act
GEC	Global Environmental Change platform (Japan)
GEMTEE	General Equilibrium *Model* for Taiwanese Economy and Environment
GEO	Group on Earth Observations
GEOGLAM	GEO Global Agricultural Monitoring Initiative
GEOGLOWS	GEO Global Water Sustainability initiative
GEOSS	GEO System of Systems
GEWEX	Global Energy and Water Cycle Experiment
GCI	GWSP Global Catchment Initiative
GHG	Greenhouse gas
GOSAT	Greenhouse Gases Observing Satellite
GPM	Global Precipitation Measurement
GRACE	Gravity Recovery and Climate Experiment
GWSP	Global Water System Programme
HLPF	UN High-level Political Forum on Sustainable Development

ICSU	International Council for Science
IGBP	International Geosphere-Biosphere Programme
IHDP	International Human Dimension Programme on Global Environmental Change
IPBES	Intergovernmental science-policy Platform on Biodiversity and Ecosystem Services
IPCC	UN Intergovernmental Panel on Climate Change
ISSC	International Social Science Council
JCM	Joint Credit Mechanism
JCOPE	Japan Coastal Ocean Predictability Experiment
KAN	Knowledge-Action Network
MDG	Millennium Development Goals
MFM	Mass flow model
NASA	National Aeronautics and Space Administration
NOAA	*National Oceanic and Atmospheric Administration*
NPP	Net Primary Production
OECD	Organization for Economic Co-operation and Development
PMI	Permafrost index
PPT	Public-private partnership
RIHN	Research Institute for Humanity and Nature
SDG	Sustainable Development Goals
SDSN	Sustainable Development Solutions Network
SGD	Submarine Groundwater Discharge
SHAW	Simultaneous Heat and Water model
SI	Stable isotope
SIMSEA	Sustainability Initiative in the Marginal Seas of South and East Asia
SMAP	Soil Moisture Active Passive mission
SMOS	Soil Moisture and Ocean Salinity mission
SRA	Strategic Research Agenda
SST	Sea surface temperature
SWFP	Sustainable Water Future Programme
SWOT	Surface Water Ocean Topography mission
UN	United Nations
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
USAID	U.S. Agency for International Development
USGS	U.S. Geological Survey

VIACS	Vulnerability Impacts Adaptation Climate Services Advisory Board
WCRP	World Climate Research Programme
WDI	Water deficit index
W-E-F	Water-Energy-Food
WSLN	Water Solution Lab Network
WTP	Water treatment plant

Appendix B

AGENDA (as of March 17, 2016)

FUTURE EARTH WATER-ENERGY-FOOD NEXUS WORKSHOP:
"Governance transformation and integrated information for the W-E-F Nexus"
Research Institute for Humanity and Nature (RIHN) in Kyoto, Japan

April 4-6, 2016

This workshop is the third in a series being held by the Future Earth Project "Governance transformation and integrated information for the W-E-F Nexus." All sessions will be held in lecture hall.

Monday, April 4, 2016

08:30-09:00	Registration	Presenters
09:00-10:35	Introduction *Chair: Aiko Endo, Minutes: Joseph Arbiol* 1) Welcoming remarks (10m) 2) Introduction of Future Earth WEF Project and the purposes of this workshop (20m) 3) Introduction of the SWFP (20m) 4) Introduction of the Future Earth and Nexus (10m) 5) Introduction of RIHN Nexus project (15m) 6) Discussion (20m)	1) Tetsuzo Yasunari 2) Richard Lawford 3) Claudia Pahl-Wostl 4) Makoto Taniguchi 5) Aiko Endo
10:35-10:50	Break	
10:50-12:20	Panel on Understanding the complexity of W-E-F Nexus system *Chair: Anik Bhaduri, Minutes: Pedcris Orencio* After each presenter will make 10 minute presentation (50 minutes), the floor open for targeted discussion (40 minutes)	1) Onanong Tapanapunnitikul 2) Shinji Kaneko 3) Yu-Pin Lin & Tsair-Fuh Lin 4) Jiaguo Qi 5) Denis Ojima
12:20-13:30	Lunch break	
13:30-15:00	Panel on Approaches on different spatial (vertical and horizontal dimensions) and temporal scales (e.g. GEO, telecommunication, future scenario) *Chair: Jiaguo Qi, Minutes: Max Spiegelberg* After each panel member will make 10-minute presentation (50 minutes), the floor will open for targeted discussion (40 minutes)	1) Ailikun 2) Toru Miyama 3) Golam Rasul 4) Cat Downy 5) Richard Lawford

15:00-15:20	Break & group photo	
15:20-16:50	Panel on water-food nexus from the perspective of fisheries, livestock and waste *Chair: Toru Nakashizuka, Minutes: Pedcris Orencio* After each panel member will make 10-minute presentation (50 minutes), the floor will open for targeted discussion (40 minutes)	1) Ching-Cheng Chang 2) Qinxue Wang 3) Masahiko Fujii 4) Jun Shoji 5) Osamu Tominaga

Tuesday, April 5, 2016

09:00-09:20	Summary from Day 1	Claudia Pahl-Wostl
09:20-10:50	Panel on Methods of W-E-F Nexus for ID and TD *Chair: Aiko Endo, Minutes: Joseph Arbiol* After each panel member will make 10-minute presentation (50 minutes), the floor will open for targeted discussion (40 minutes)	1) Chad Higgins 2) Hong Yong 3) Temirbek Bobushev 4) Pedcris Orencio 5) Fi-John Chang
10:50-11:05	Break	
11:05-12:35	Governance in the W-E-F (institutional arrangement, legislation, policy, capacity development, stakeholder involvement) *Chair: Hong Yong, Minutes: Max Spiegelberg* After each panel member will make 10-minute presentation (50 minutes), the floor will open for targeted discussion (40 minutes)	1) Kenshi Baba 3) Masayo Hasegawa 3) Zaw Naing 4) Shih-Hsun Hsu 5) Claudia Pahl-Wostl
12:35-13:35	Lunch break	
13:35-13:45	Introduction to breakout groups	Richard Lawford
	Breakout groups meet Participants will have the options of joining the breakout group of their reference. 1. Observations and science (Lecture hall) *Facilitator: Richard Lawford* *Minutes: Pedcris Orencio* 2. Governance and management (Seminar room 1-2) *Facilitator: Claudia Pahl-Wostl* *Minutes: Max Spiegelberg*	

15:45-16:00	Break	
16:00-17:00	Reports from the breakout groups	

Social gathering: Local restaurant in Shijo

Wednesday, April 6, 2016

09:00-09:20	Summary from Day 2	Richard Lawford
09:20-10:50	Formulating network with Future Earth Nexus KAN and SDGs *Chair: Makoto Taniguchi, Minutes: Max Spiegelberg* After each presenter will make 10 minute presentation (50 minutes), the floor open for targeted discussion (40 minutes)	1) Sandrine Paillard 2) Denis Ojima 3) Anik Bhaduri 4) Norichika Kanie 5) Tetsuzo Yasunari
10:50-11:05	Break	
11:05-11:35	Discussion of proposals *Chair: Anik Bhaduri, Charles Vörösmarty*	
11:35-12:35	Summary Discussion Workshop summary, conclusions, and adjournment *Chair: Claudia Pahl-Wostl, Minutes: Joseph Arbiol*	
12:35-13:35	Lunch Break	

Research Institute for Humanity and Nature
Inter-University Research Institute Cooperation, National Institutes for the Humanities
457-4 Kamigamo Motoyama, Kita-ku
Kyoto 603-8047,
JAPAN

Future Earth
Montreal Global Hub
Suite 1020, 1250 Guy Street
H3H 2T4 Montreal, Quebec
CANADA

Sustainable Water Future Programme
Level 4
Sir Samuel Griffiths Building (N78)
170 Kessels Road, Nathan 4114
Queensland
AUSTRALIA

For more information on the Research Institute for Humanity and Nature,
see www.chikyu.ac.jp/wefn/english/index.html or write to a.endo@chikyu.ac.jp

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