

Bridging Food, Energy and Water nexus: Developing methodologies, risk management systems, substantive solutions and decision tools



Shang-Lien Lo

Graduate Institute of Environmental Engineering
National Taiwan University





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Food-Energy-Water Nexus (FEW Nexus)

- The Nexus is the connection between **Food-Energy-Water**. With a global population of 8.5 billion in 2030, we'll need 60% more food, 45% more energy and 30% more water. **Sustainably managing** this resource interdependence will be one of the 21st century's central challenges for humanity.
- There is a critical need to equip **decision makers** with **research, new tools and capacity** to address the nexus challenge and to plan ahead for change in the **ecological, social and economic systems** that provide our food, energy and water.
- The objective of bridging FEW Nexus is to **optimize Food, Energy and Water security**.

- This talk will focus on my group's recent work on bridging FEW. We address the importance of adopting an integrated and interdisciplinary approach. **Four subprojects** are undertaking cutting-edge research to demonstrate for decision-makers the positive and negative consequences of their investments and policies, today and tomorrow.
- Together, these create a **useful decision-support system for FEW Nexus**.
 1. Explore Food-Energy-Water nexus **elements and indicators**.
 2. Analysis of **Risk and Uncertainty** of FEW Nexus;
 3. Studies on **Scales and Solutions** of Food-Energy-Water Nexus;
 4. Development of a **comprehensive tool** for Food-Energy-Water Nexus.



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Objectives

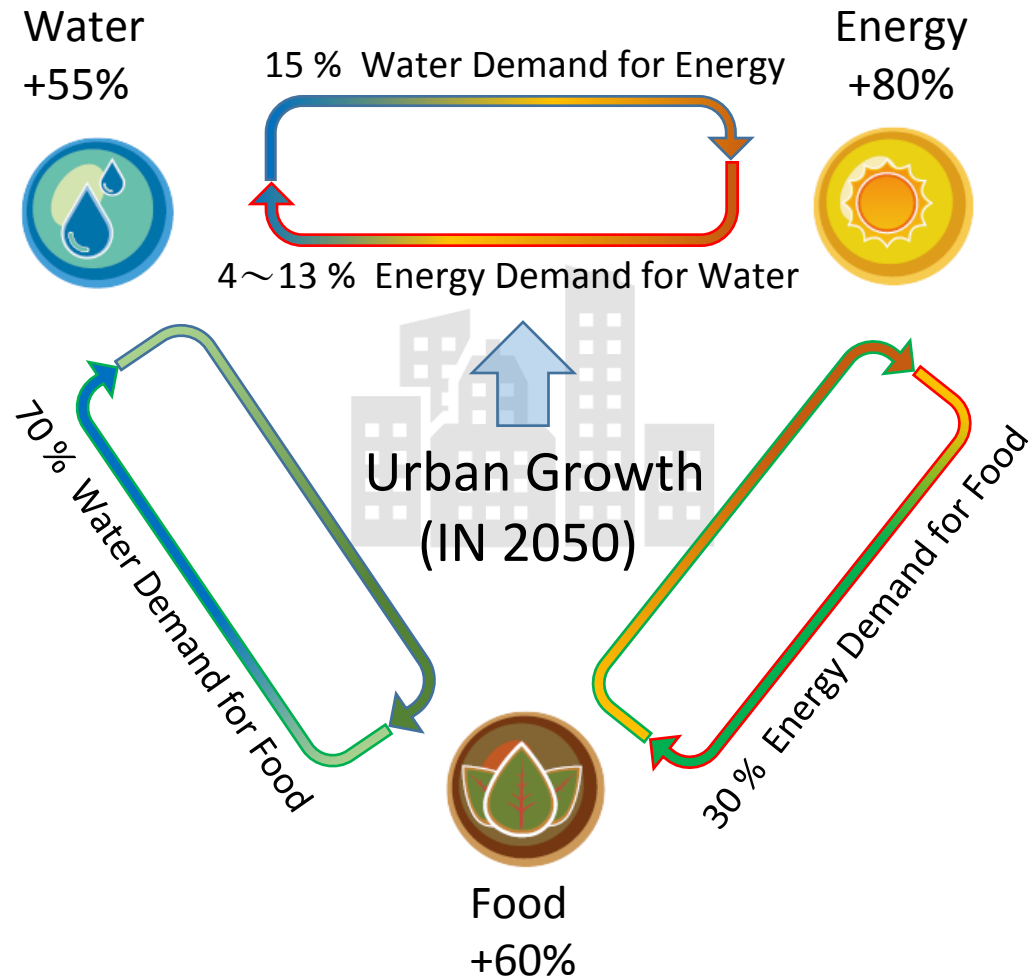
Project 1. Explore Food-Energy-Water nexus elements and indicators

- To discuss **linkages** between Food-Energy-Water and develop **indicators** for FEW Nexus.
- To explore a **modified DPSIR** (Driving forces, Pressure, State, Impact and Response) **model** for multiple Food-Energy-Water security objectives.
- Integrated **DPSIR** and **ESA (ecosystem services assessment)** for FEW Nexus in the case of biofuel energy development.

Project 2. Analysis of Risk and Uncertainty of FEW Nexus

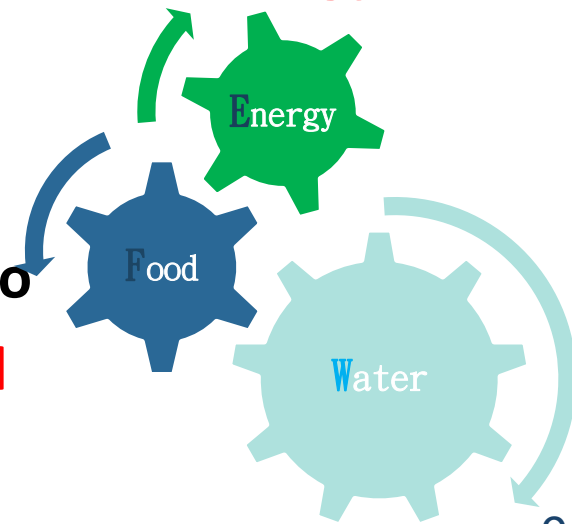
Current and Future Risk of Food, Energy and Water Nexus

- By 2050, demands of food, energy and water will rise up to 50%~80% because of urban growth.(IRENA, 2015; IEA, 2015)
- Driving force from social and economic conditions in urban area will increase demands of food, energy and water nexus.(WBCSD, 2014; FAO, 2014)
- Evaluating risk and uncertainty of food, energy and water nexus can provide an opportunity to improve the resource efficiency in urban area.



- To identify the **intensity** in terms of **supply-demand flows** of food, energy and water at the urban scale.
- To construct the assessment of **risk and uncertainty** of food, energy and water nexus.
- To clarify the **spatial driving forces** derived from social and economic factors.
- To develop the urban-scaled **risk and vulnerability maps** which facilitate appropriate strategies in terms of resource management.

- Under climate change, the nexus theory emphasize the connection of FEW security, which is based on the increasing shortage of water resources.
- Shortage of water resources may result in the global food production decreasing, and finally lead to the competition between food security and biofuel production. Therefore, the focus is **on how to use the minimum water and energy to produce the maximum food.**
- Different region and background would influence the scientific solutions of Nexus, so **the objectives are established and practiced the solutions among local circumstances.**



Development of a comprehensive assessment tool

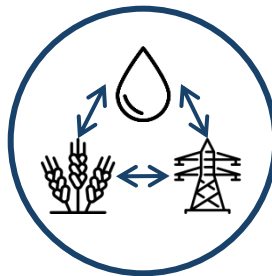
- Improve resources use efficiency
- Support decision making
 - Represent overall impacts and benefits.
 - Avoid overlooking of important issues that should be analyzed.

(Ringler et al., 2013)

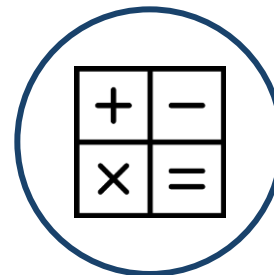
- The nexus tool includes 3 parts:



Database



Conceptual
model

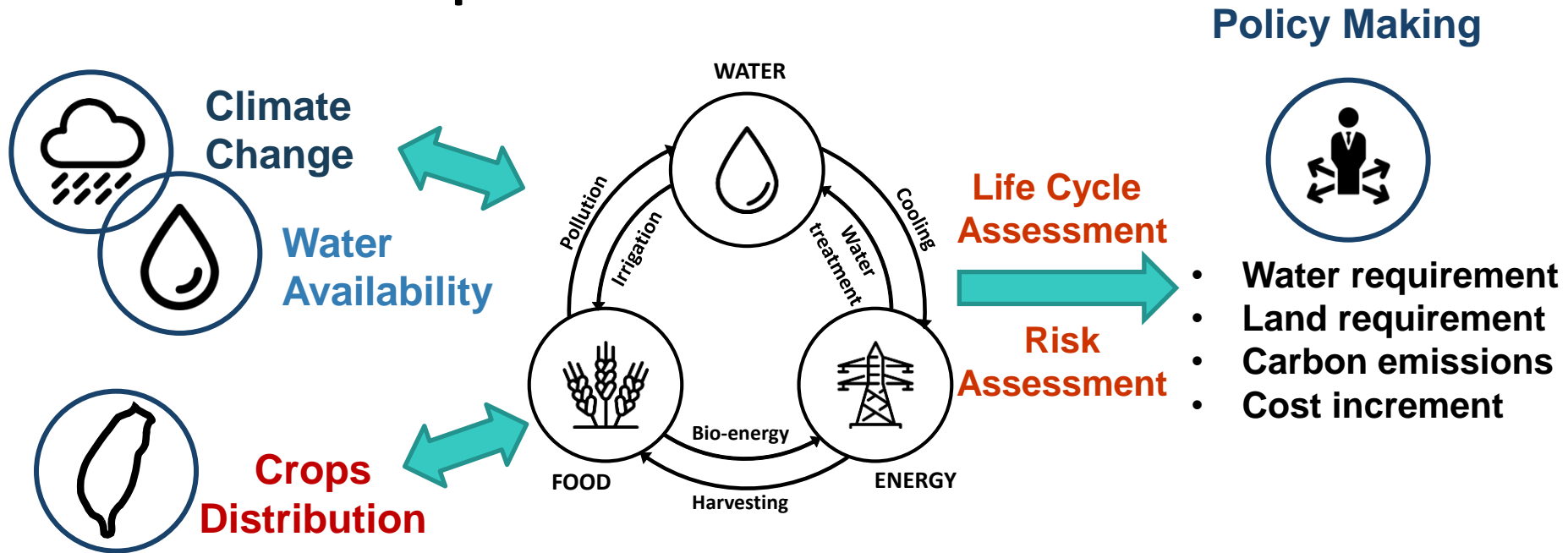


Calculation
methods

(Bazilian et al., 2011)

Improvements of the nexus tool

- Water availability models such as HSPF and SWMM are incorporated in the database.
- **Food crops and bioenergy crops** with distribution are selected as inputs.



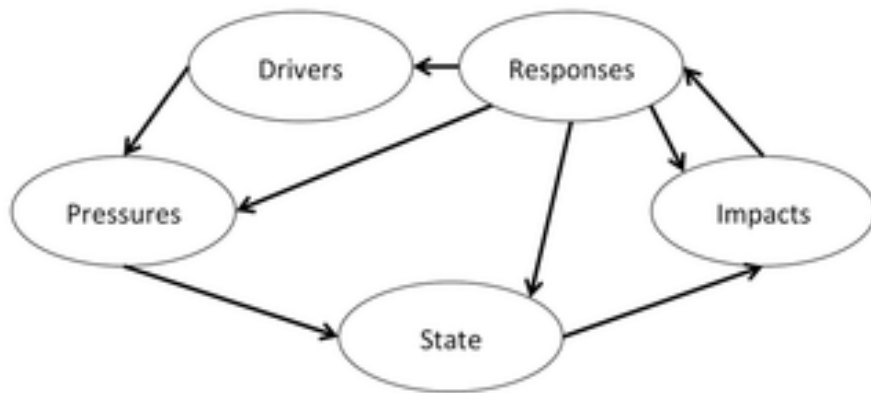
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Methods and expected outcomes

Project 1. Explore Food-Energy-Water nexus elements and indicators

First year

- Integrated **DPSIR** (Driving forces, Pressure, State, Impact and Response) model which is a widely used tool for complex environmental issue.
- The DPSIR approach encourages and supports decision-making. It also represents a systems analysis view:- **social and economic developments** exert **pressure** on the environment and, as a consequence, the **state** of the environment changes. This leads to **impacts** on ecosystems that may **response** and feed back on the driving forces.



Expected outcomes

- Analyze weak point of current model under **multiple destinations** for FEW Nexus.
- Explore a **modified DPSIR framework** for FEW Nexus.

- Demonstrate “**LIFEWAY** (Linked Indicators for Food, Energy and Water Availability)” based on SDGs (Sustainable Development Goals).

Project 1. Explore Food-Energy-Water nexus elements and indicators

Second year

- Integrating **ecosystem services assessment** approaches, **DPSIR** model and **SDGs** for FEW Nexus indicators
 - Mapping supply, demand and budget of water, food and energy services by Integrated Valuation and Ecosystem Services and Trade-offs (**InVEST**) model.
 - Demonstrate “**LIFEWAY**” based on ecosystem services assessment.



Project 1. Explore Food-Energy-Water nexus elements and indicators

Third year

1. MODIFIED MODEL ✓
2. LINKED INDICATORS ✓
3. INDICATOR USERS
We need **stakeholders** to lead ✓

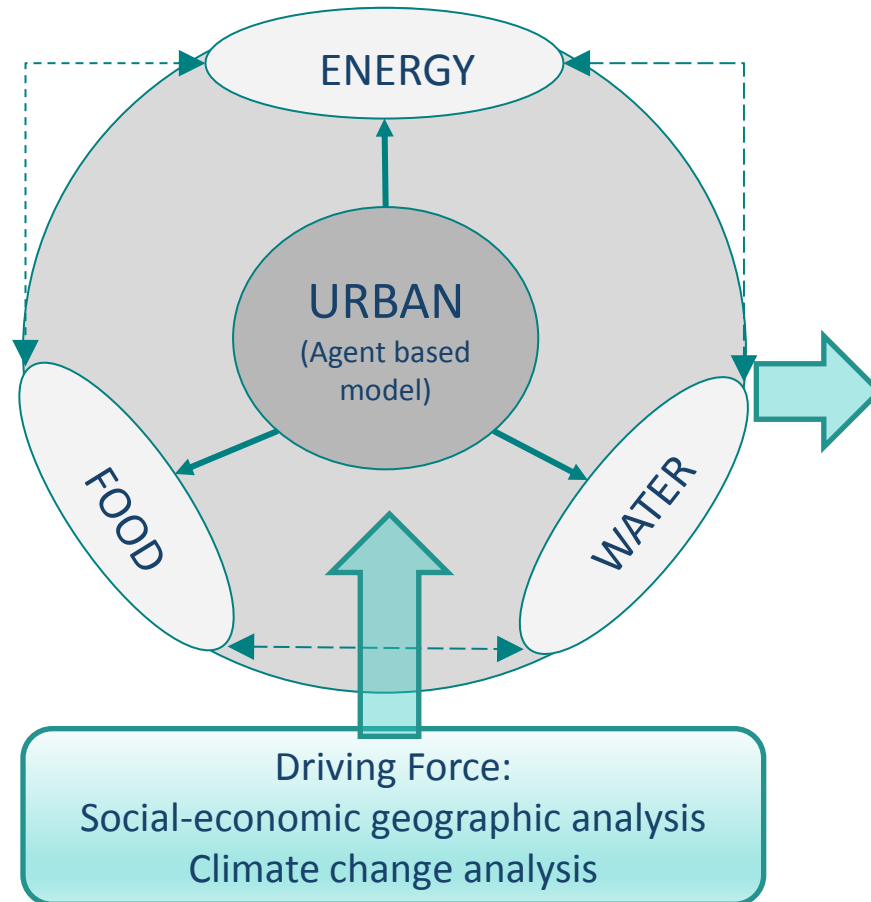
• THE CHALLENGE

- Current Decision Support does not give sufficient insight for managing change in the **ecological, social** and **economic** systems that provide our food, energy and water.
- Pilot Analysis
 - Using modified DPSIR framework and ecosystem services assessment outcomes, informed by **stakeholders** to develop **actionable indicators** that measure the value of ecosystem services and integrate these measures into policy decisions.
- Outcomes
 - A tested LIFEWAY indicators for FEWNexus.
 - Learning to share on indicator development and selection.
 - An evidence base for ecosystem services conservation and trade-offs.

Project 2. Analysis of Risk and Uncertainty of FEW Nexus

Framework and Methods

- **Database:** Resource inventory (food, energy and water) in urban scale.
- **Analysis:** Intensity of supply-demand of FEW Nexus by Material Flow Analysis.
- **Model:** Risk and Uncertainty of FEW Nexus by ABM model.
- **Strategy:** Changing human behavior to FEW Nexus.

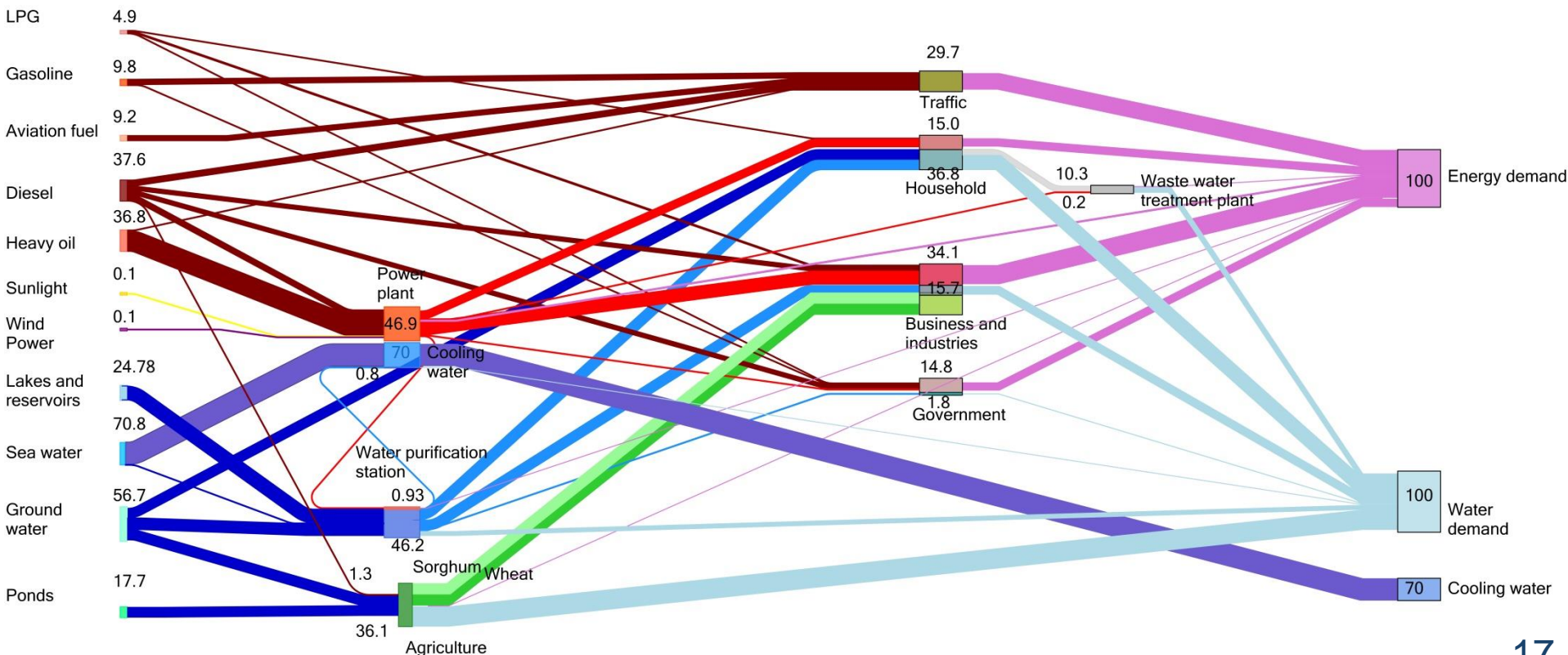


- ❑ Risk assessment of food, energy and water nexus.
- ❑ Analysis of impacts from external driving factors (such as social, economic, policy and climate...)
- ❑ Estimating incremental risk and uncertainty of food, energy and water nexus.

Project 2. Analysis of Risk and Uncertainty of FEW Nexus

First year

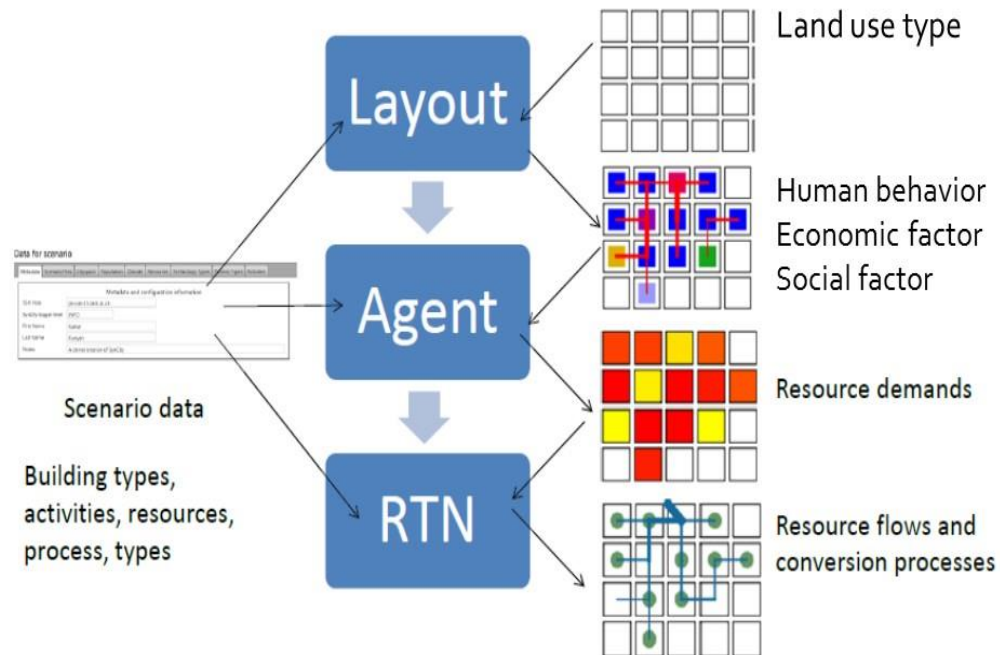
- To distinguish nodes and interventions of supply-demand of FEW Nexus by Material Flow Analysis (MFA).
- To evaluate intensity into database of FEW Nexus at the urban scale.
- To identify the relationships of risk and impact of FEW Nexus .



Project 2. Analysis of Risk and Uncertainty of FEW Nexus

Second year

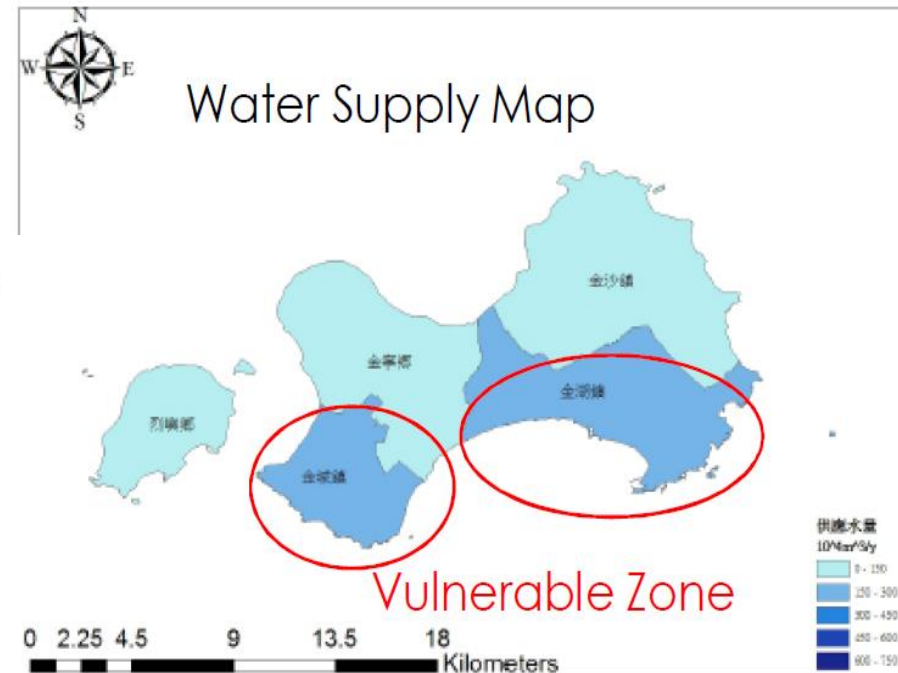
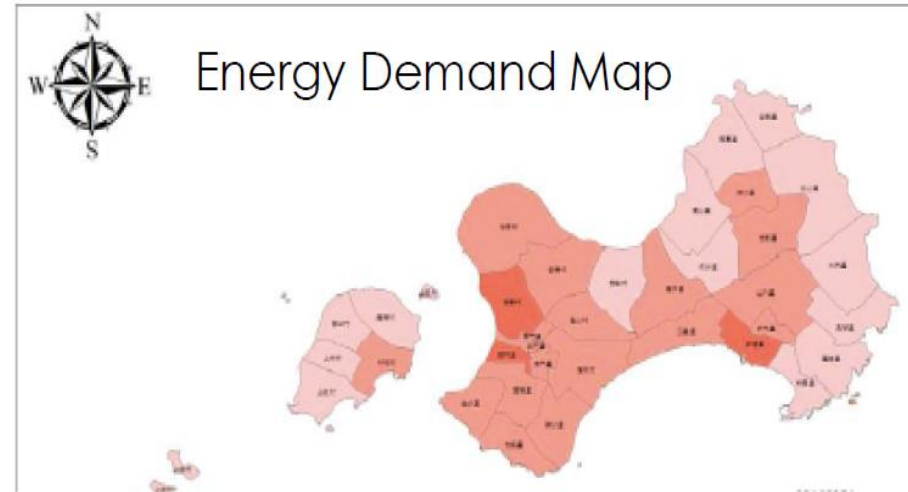
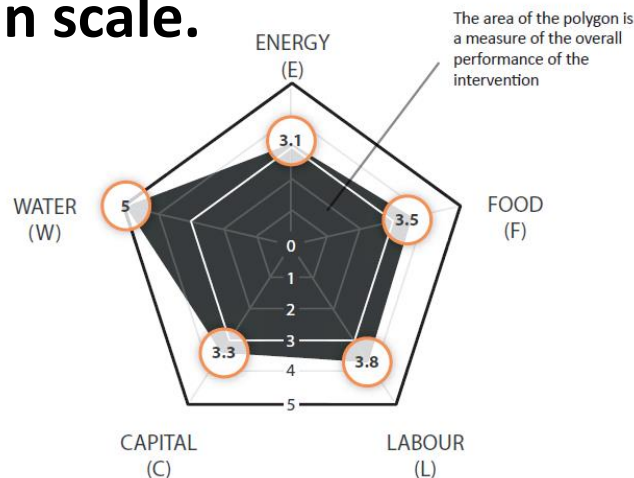
- To identify driving forces from social-economic aspects with land use by Geographic Information Analysis (GIS).
- To analysis spatial variations of intensity of demands of FEW Nexus at the urban scale.
- To establish conceptual model of risk assessment of FEW Nexus at the urban scale.
- To evaluate the incremental risk and uncertainty combining with resource consumption (or demands) intensity and driving forces.



Project 2. Analysis of Risk and Uncertainty of FEW Nexus

Third year

- To build up a risk radar map of FEW Nexus at the urban scale.
- To map vulnerable zone of resource supply for demand intensity of FEW.
- To propose the strategies and roadmap of resource management of FEW Nexus at the urban scale.



Project 3. Studies on Scales and Solutions of Food-Energy-Water Nexus

Work Planning

1st year

To investigate the different scale of FEW Nexus



2nd year

To propose and investigate the solutions



3rd year

To develop and promote the solutions

Literature collecting and data analyzing

- Data of using water and energy resources to produce **specific crops in Taiwan or other countries**.
 - Urban and suburban
 - Open-field culture or protected culture

Solving solutions studying

- Base on the 1st year results, and then **discuss with other sub-programs** to provide solving solutions and practices in urban area.

Solving solutions developing & promoting

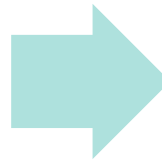
- Discuss the performance and give **a feedback to sub-program II and IV** for improving and **establishing a stable decision-make platform**.
- To improve literacy of the public in FEW Nexus with **the plan of environmental education** and decrease the huge impact.

Project 3. Studies on Scales and Solutions of Food-Energy-Water Nexus

First Year

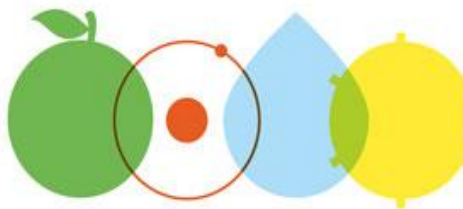
Work content

- Collect the data of Taiwan or other countries of using water and energy resources to produce specific crops (e.g. corn, vegetables) in suburban and urban regions, or by the open-field or protected culture.
- Refer to the adaptation cases to climate change which were strongly correlated with FEW Nexus when collecting the FEW literatures.



Expected results

- Confirm the **water use efficiency (WUE)** of major crops and the **source and cost of water/energy** in different region.
- Find out the growing crop species and cost difference of growing style in urban and suburban regions.
- Data analyzing and for reference of the further plans.



THE NEXUS NETWORK

new connections in food, energy, water and the environment

An ESRC investment

<http://steps-centre.org/engagement/nexus-network/>

Project 3. Studies on Scales and Solutions of Food-Energy-Water Nexus

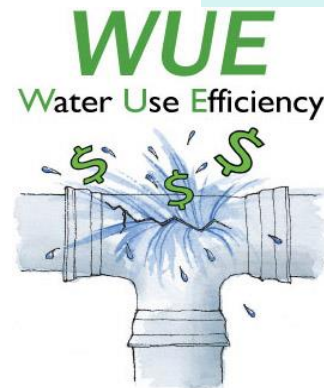
Second Year

Work content

- Base on the 1st year results to propose the solving solutions and practices of suburban and urban regions in our 2nd year study.
- Suburban : increase WUE by
 - **Improve growing styles** or
 - **Choosing right crops**
- Urban : increase SUE by
 - **Vertical growing**
 - **Edible landscaping**
Ornamental trees → **Fruit trees**
Flowering crops → **vegetables and herbs**

Expected results

- Confirm the feasibility and the pros & cons after actual practice.
- Food crops :
 - Suburban → **increase WUE** (**water saving**)
 - Urban → **increase SUE** (space use efficiency) (**energy saving / food increasing**)



Project 3. Studies on Scales and Solutions of Food-Energy-Water Nexus

Second Year

Vertical growing

- Yield could be increased by vertical growing in the limited urban space.
- **How to do :**
 - right cultivars or species
 - cultivation and management
 - feasibility evaluation
 - pros and cons analysis



Project 3. Studies on Scales and Solutions of Food-Energy-Water Nexus

Second Year

Edible landscaping

- The multi-functional use of food-producing plants as design features in the residential landscape.
- Ornamental trees → Fruit trees
- Flowering crops → vegetables and herbs
- To investigate the species choosing, management and the pros & cons of practices.



<http://s.hswstatic.com/gif/food-crops-1.jpg>



<http://www.motherearthliving.com/~media/Images/MEL/Editorial/Articles/Magazine%20Articles/2011/09-01/Eat%20Your%20Yard%20How%20to%20Design%20an%20Edible%20Landscape/NH-SO11-ediblelandscaping-swiss-chard.jpg>



https://sowswell.files.wordpress.com/2012/11/potager_veg.jpeg

Project 3. Studies on Scales and Solutions of Food-Energy-Water Nexus

Third Year

Work content

- Discuss the performance and give a **feedback** to other sub-programs for data improving, and establish a **stable decision-make platform**.
- Setup a **demonstration site**.
- To **improve literacy of the public in FEW Nexus** with the plan of **environmental education**.



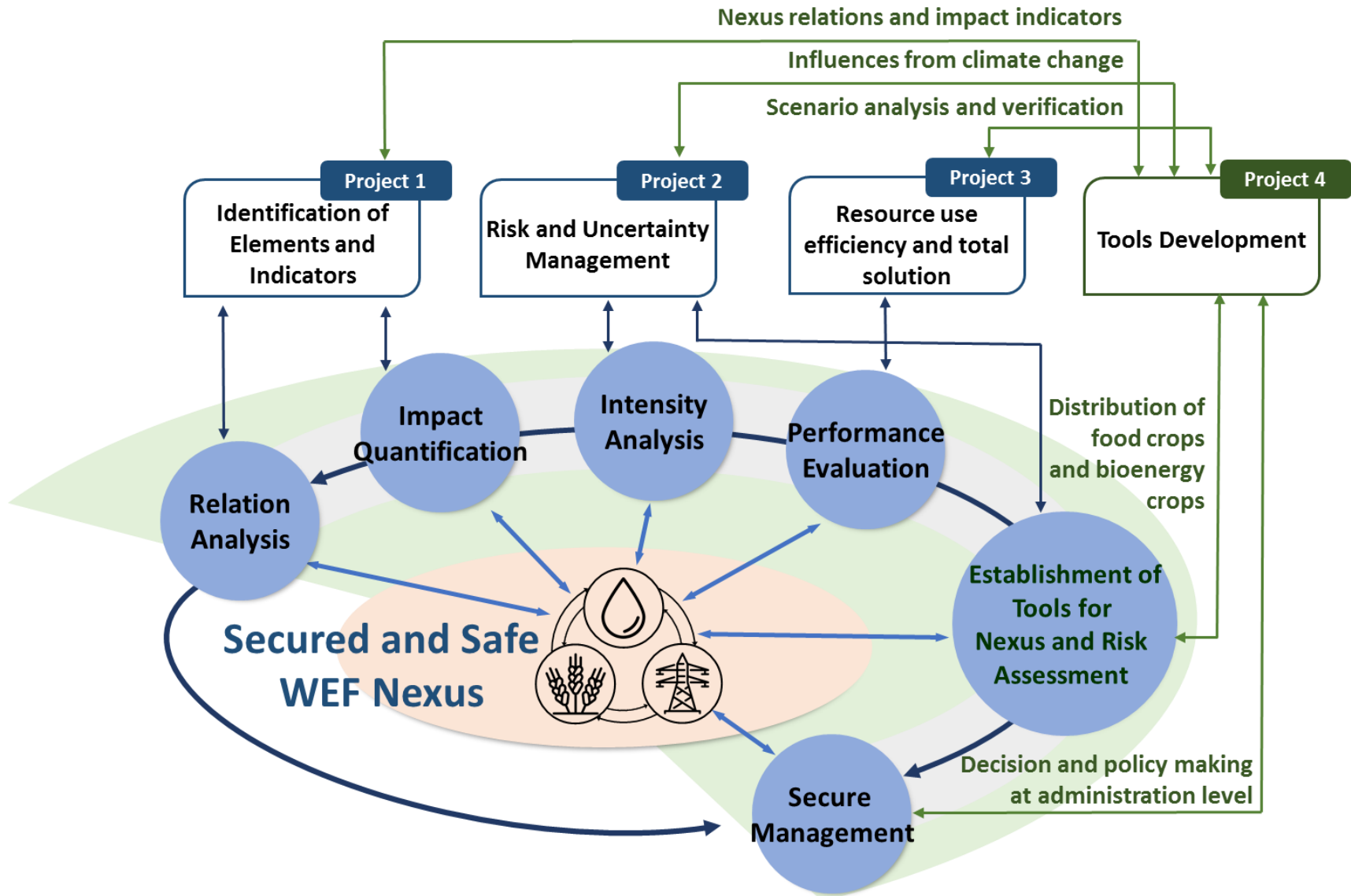
Expected results

- Feedback for data improving and **setup a stable decision-make platform**.
- Create more **sustainable economics and solutions**.
- **Decrease the huge impacts** to the FEW Nexus under climate change influence.



Project 4. Food-Energy-Water Nexus: Tool Development

The tool plays an important role in project integration



First year

• A Taiwan-based FEW nexus tool



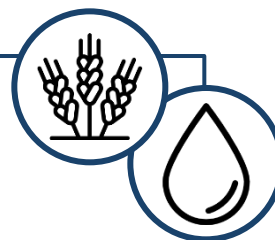
System Database

- Life cycle inventory data:
Including water, energy, resources...
- Life cycle impact assessment methods
- **GIS data- Crops distribution**
- **Water availability forecasting**

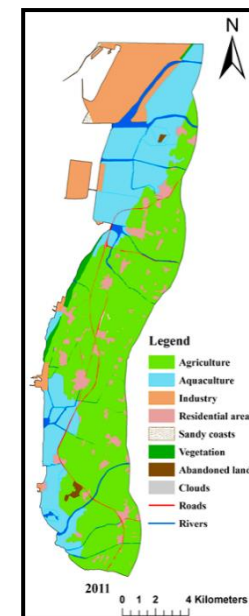


User Surface

- Crops scenarios
- Water scenarios
- Import scenarios
- Climate change scenarios
- Weighting factors based on policy targets



EX:
Coastal
Land
Use in
Yunlin
County



Evaluation on data availability and calculation mechanisms

Project 4. Food-Energy-Water Nexus: Tool Development

Second and Third Years



- **Development of FEW nexus models based on food crops and bioenergy crops in GIS distributions.**
 - Incorporating **vulnerability maps of supply and demand** (outcomes from project 1 & 2).
 - **Site specific** data that integrates the influences from **climate change** and **crops distribution**.
- **Conducting case studies for **scenario analysis** and sensitivity analysis.**
- **Policy evaluations:** energy, water and food policies, land use plans or green-house-gas emission mitigation strategies.

Thanks for listening