Center for Sustainability Science
Academia Sinica

2017 Annual Report of Center for Sustainability Science, Academia Sinica

Foreword

In order to promote scientific research on topics that can contribute to the sustainable development of human society on our planet, Academia Sinica established the Center for Sustainability Sciences (CSS) in 2012. The Center has worked to integrate and strengthen sustainability sciences by means of interdisciplinary teamwork here at Academia Sinica. At the same time, scientific knowledge itself also needs to be transformed into concrete plans of action that can overcome the dilemmas threatening the sustainable development of human society. Therefore, a substantial part of the Center's mission involves the search for viable solutions, an ideal that has been consistently implemented in our research programs. The past five years have witnessed the successful integration of research teams from a variety of scientific fields in Academia Sinica as well as other universities, with a number of projects delivering significant results and others making solid progress. At the same time, due to increasing pressures resulting from global changes, efficiently working out solutions for the above-mentioned problems requires extensive international coordination, especially since the problems of sustainable development we face today are usually regional, if not global. Therefore, experience in international exchange efforts plays an important role in speeding up knowledge accumulation for forming timely and effective plans of action. Due to its participation in the efforts of the International Science Council (ISC; merged from the ICSU and ISSC in July 2018), of which Academia Sinica is a member, the Center's mission has evolved to include the support of two specific international programs: Integrated Research on Disaster Risk (IRDR) and Future Earth. These programs provide avenues for organizing and taking part in additional international research efforts involving sustainability sciences. This annual report highlights the major achievements of Center's research programs and its activities in international programs. I look forward to your suggestions and comments to help the Center improve and achieve new progress in the future.

Mei-Yin Chou

Mei-Yin Chou
Chairman, Center for Sustainability Science
Academia Sinica

Editor's Notes

This report updates and highlights the 2017 status and activities of the Center for Sustainable Science (CSS), Academia Sinica. For the research programs, seven projects are invited to be the showcase for novel findings. Two out of seven are energy technology related. One is seeking ways to efficiently produce biogas; another is to develop new materials that can effectively transfer heat into electricity. The third project is about food security, which provides new knowledge on rice growth in case our society faces the fact of environmental changes. The forth project is to find management strategy for sustainably protecting the living coral reefs. Another two projects work on topics related to human health: one is a high-resolution assessment on the heat wave vulnerability; the other is to find determinants for the frailty and depression in aged population. The last invited project is to establish an appraising model and its database for the evaluation on policies toward sustainable development. Although projects presented herein cover only nine of seventeen global SDGs, we believe more are coming in the near future due to the continuous endeavor of CSS. Further more, CSS sponsors two international programs: IRDR and Future Earth. All participated events and activities in 2017 are also presented in this report. By more engagement with global task forces, CSS intends to synchronize the efforts of the international society towards sustainable development. We welcome any comment to this report and to CSS. Lastly we would like to thank all the hard work of the program managers and our CSS office crews in presenting and preparing the content for this report.

Yu Wang
Distinguished Visiting Chair, Center for Sustainability Science
Academia Sinica

Yue-Gau Chen
Executive Secretary, Center for Sustainability Science
Academia Sinica

Introduction

Since established in 2012, the Center for Sustainability Science (CSS), Academia Sinica keeps endeavoring transdisciplinary research on the sustainability sciences, in particular on earth system and its interactions with human activities. With the advantage of a wide range of research fields in the Academia Sinica, mainly grouped into three divisions: the Physical Sciences, Life/Medical Sciences, and Humanity/Social Sciences, CSS is intrinsically expected to integrate the research powers and to promote the transdisciplinary sustainability sciences. To implement such transdisciplinary goal CSS has provided research programs with focuses on prioritized social problems of sustainable development, which human society is seriously facing today. It is hence expected that CSS research programs can eventually provide effective solutions not only for worldwide concerns but also for Taiwan's demand on sustainable development.

As far as we know, to find the appropriate way for sustainable development needs worldwide efforts. CSS is also responsible to help engage the international network; thus is now hosting two international programs. One is The Integrated Research on Disaster Risk-International Centre of Excellence (IRDR-ICoE), which was established in 2011 with the support of International Council for Science (ICSU). IRDR-ICoE serves as an international platform for networking disaster risk related interdisciplinary researchers to strengthen integrated collaborations. Another international program is the Future Earth, a major scientific endeavor supported by the International Science Council (ISC) to promote the sustainability sciences. Collaborating with Future Earth, Taipei, CSS is responsible to organize events to engage related international activities.

Missions

The missions of CSS can be divided into three categories:

(1) to organize, coordinate and evaluate transdisciplinary sustainability-related research programs.

(2) to support sustainability science related international programs. IRDR ICoE-Taipei and Future Earth are currently two main tasks.

(3) to provide objective advice to our government on matters of sustainable development.

Organization

Members of the Center for Sustainability Science Organization Chart

Executive Office

Chairman:
Mei-Yin Chou

Distinguished Visiting Chair:
Yu Wang

Executive Secretary:
Yue-Gau Chen

Deputy Executive Secretary:
Louise Liang-Yung Wei

Director of International Programs:

Shih-Chun Candice Lung

Jian-Cheng Lee

Officers of International Programs:

Chia-Hsing Jeffery Lee

Si-Yu Yu

Program managers:

Yu-Fang Hsu

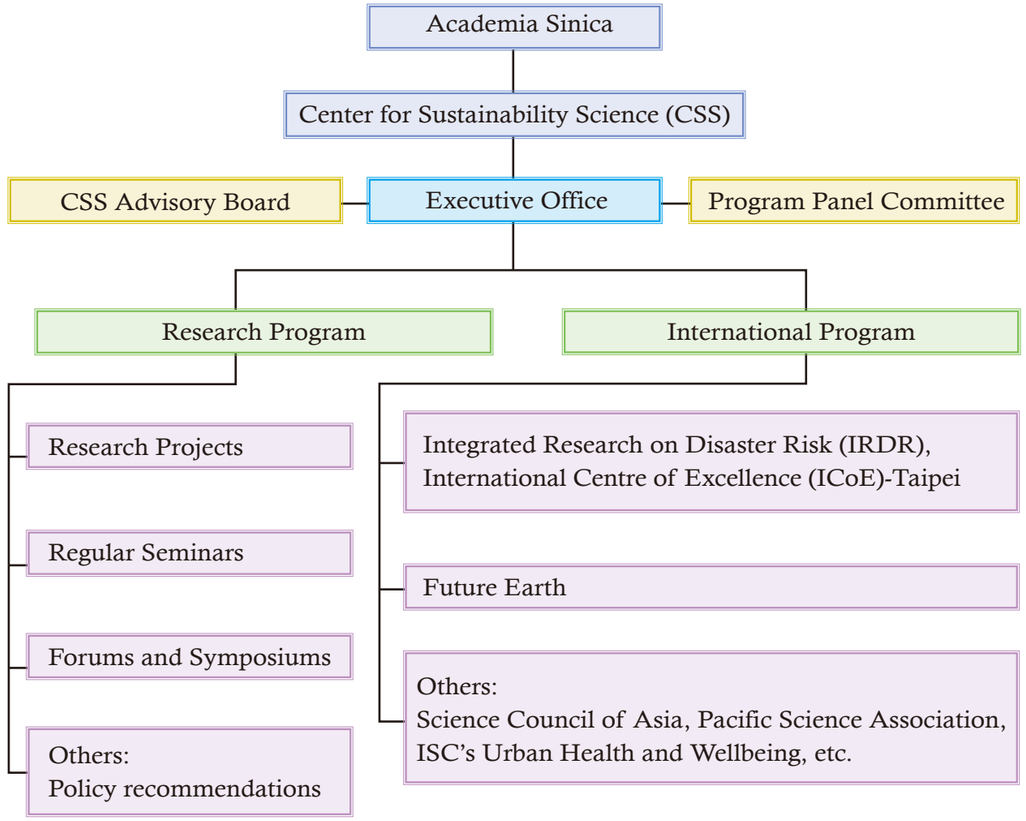
Li-Wen Lee

Tzu-Hsuan Yang

Yun-Han Chin

Chia-Hui Yen

Center for Sustainability Science Organization Chart



Sustainability Science Research Program

Sustainability science covers a wide spectrum of research fields including nature science, social science, and all supporting technology. To find solutions for the problems that human society is facing nowadays transdisciplinary research has been confirmed as an effective way. CSS therefore organizes research programs to target on prioritized transdisciplinary subjects.

2017 six priority subjects for CSS research program:

◊ Climate Change and Human Well-being
◊ Natural Disaster Reduction and Adaptation
◊ Energy and Decarbonization Technologies
◊ Health-Related Issues: Aging Society
◊ Food Security and Safety
◊ Human Dimensions of Sustainable Development

2017 Annual main themes:

◊ Energy and Decarbonization Technologies
◊ Food Security
◊ Ecological Conservation and Sustainable Use of Biodiversity Resources

2017 Project status

In 2017, CSS conducted and supported 15 integrated projects including 15 main projects and 66 sub-projects.

Energy and Decarbonization Technologies

Biotechnology of Anaerobic Digestion Producing Biogas Energy

Shih-Hsiung Wu

Energy and Decarbonization Technologies

Development of Novel Thermoelectric Materials for Sustainable Energy

Kuei-Hsien Chen

Food, Air, and Water Security and Safety

Effects of Environmental Changes on Rice Growth and Production in Taiwan

Ming-Che Shih

Earth System under Global Changes

Linking Ecology to Management for Sustaining Resources of Coral Reefs Facing Climate Changes

Chaolun Allen Chen

Health and Environmental Changes

Integrated Multi-source and High-resolution Heat Wave Vulnerability Assessment of Taiwan

Shih-Chun Candice Lung

Health and Environmental Changes

A Blueprint for Healthy Aging: Determinants and Prevention of Frailty and Depression in Elderly

Wen-Harn Pan, Hsing-Yi Chang

Transformation towards Sustainable Society

Enhanced GEMTEE (General Equilibrium Model for Taiwan Economy and Environment) for IAM Framework-An Integrated Computable General Equilibrium Model and Database for Appraising Policies toward Sustainable Development

Ching-Cheng Chang

Biotechnology of Anaerobic Digestion Producing Biogas Energy

Project starting year: 2015
Hosting Institute: Institute of Biological Chemistry, Academia Sinica

Research Objectives

In this sustainability project, we plan to improve the efficiency of methane production in the anaerobic digestion system. We try to base it on metagenomics, proteomics-and metabolomics analyses to figure out the complicated microbial communities and try to pick out the key microorganisms in anaerobic digesters which can stabilize the system and enhance the methane production. For the purpose of sustainable application in the biogas issue, we are trying to promote the livestock-owned anaerobic digesters to produce the methane as sustainable energy for maintaining the livestock use. This sustainable goal can improve the environmental protection which is surround the livestock in Taiwan, and significantly decrease the electricity fee at the same time. It provides a potential way to decrease the electricity demand which can solve the energy issue in Taiwan.

Main Results to Date

Optimization of the anaerobic co-digestion system

The BMP tests and anaerobic co-digestion system to degrade Ma bamboo biomass coupled with pig manure were conducted to produce methane gas. As shown in the BMP test, it took around 1.5 months for Ma bamboo to reach a steady-state of methane production. The methane yield of BMP test for Ma bamboo as substrate could reach 0.13 liter of methane per gram volatile solids (VS) added and methane content of 52% at VS 10%. In the co-digestion tests, according to the experience in the year 2015 and 2016, we considered to operate the co-digestion tests with 5 and 10 days HRT. The anaerobic digesters in investigation of both experimental factors, ratio of swine manure and bamboo wastes as well as different temperatures (37 and 55°C) have been setup and harvested the optimal data. Four different VS concentrations (1%, 2.5%, 5%, 10%) of bamboo powder (BP) were mixed with anaerobic sludge (AS) at a ratio of 3:2 (BP:AS). It was noticed that the test of VS 10% had the highest methane yield of 126 mL/g VS added and methane content of 52%. Then the co-digestion system of bamboo biomass with swine manure was tested at 10 days HRT with five mixture ratios (0:1, 1:3, 1:2, 1:1, 1:0). 5 days HRT with three mixture ratios (1:3, 1:2, 1:1) were tested under mesophilic and thermophilic conditions. The results showed in co-digestion test (Fig. 1), at thermophilic temperature (55°C), HRT of 5 days, and 25% bamboo wastes, the best gas production performance of co-digestion tests were observed. The gas production rate (GPR), methane production rate (MPR) and methane content were 2.96 L/L/d, 1.98 L/L/d, and 66.73%, respectively.

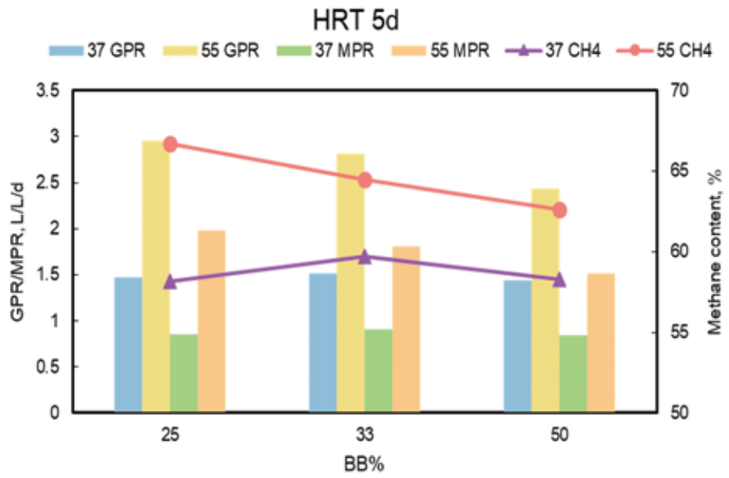


Figure 1. The performance of gas production rate (GPR), methane production rate (MPR) and methane content at HRT 5 days with different mixing ratio of bamboo powder (BP) and swine manure

Microbial interaction network in temperature dependent anaerobic digester

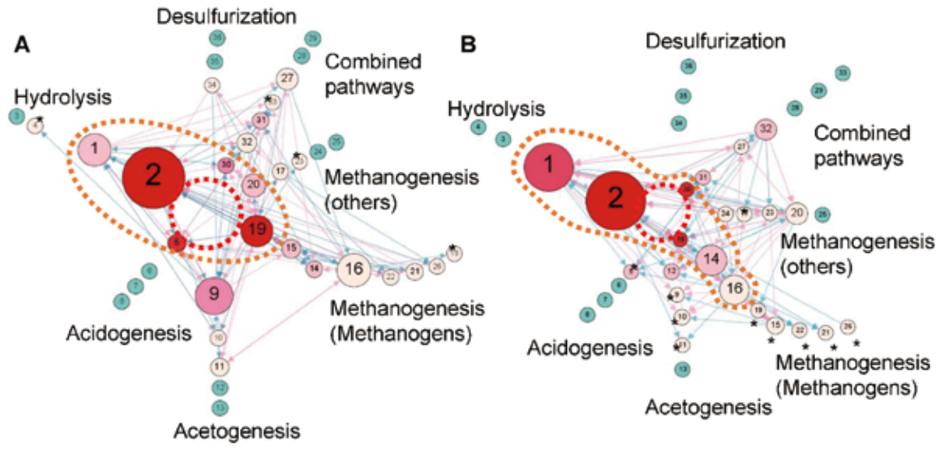
We used Illumina-based 16S rDNA sequencing to examine the complex microbial communities found in AnD digesters. Then, we developed a tool called MetaMIS (**Meta**genomic **M**icrobial **I**nteraction **S**imulator) (Shaw et al., 2016), which can predict the microbial interactions using time series data of the microbial population. With this tool, we published a first study revealing the microbial interactions in mesophilic or thermophilic anaerobic digesters (Shaw et al., 2017), and shed light on the application studies. Based on topological niche between mesophilic and thermophilic interaction networks, key microbes that potentially enhanced biogas or methane production were identified and then validated by BMP and CSTR reactors (Fig.2). The effluent substrates from the thermophilic AnD contained a lower amount of undigested biodegradable TS, i.e. high removal efficiency of TS, in the initial state compared with mesophilic AnD was highly associated with the changed microbial community at the higher temperature (Fig. 2).

The percentage of archaeal sequences (8.3-13.1%) at mesophilic temperature was higher than in the thermophilic conditions (2.2-7.9%), especially after performing genome copy number correction. All of the archaeal or bacterial sequences were classified to family-equivalent OTUs recognized in the RDP database. In total, 173 major families were identified after discarding 5 or 19 OTUs uniquely in the thermophilic or mesophilic conditions respectively. Supported by the literature (Wise et al., 2007; Saengkerdsub et al., 2007; Lu et al., 2003; Amit-Romach et al., 2004; Campanaro et al., 2016), we identified 36 microbial families which participated in biogas-related pathways (BRP). The remainders (137 OTUs) were placed into the NBRP (non-biological conversion process) group. The accumulated relative abundance of methanogens revealed that seed sludge was the major source of methanogens (45.84%) for those from mesophilic AnD (12.39%) or thermophilic AnD (7.55%) digesters. However, influent substrates from swine manure constituted a bacterial repository and provided 84.02% of its community during the process of hydrolysis, acidogenesis, acetogenesis and desulfurization.

In this study, temperature was a critical factor influencing the microbial abundance and composition. These differences in microbial communities might be controlled by the intrinsic interactions between microorganisms. Therefore, the microbial interaction networks with the 100 strongest interactive strengths from the MAnD or TAnD reactors were sketched (Fig. 2). Using eigenvector centrality, *Flavobacteriaceae*, *Methanocorpusculaceae* and *Spirochaetaceae* connected by central OTUs were the most influential in the mesophilic interaction network (dotted red circle in Fig. 2A). Under thermophilic conditions, the most influential OTUs were *Spirochaetaceae*, *Ruminococcaceae*, and *Methanomicrobiaceae* (dotted red circle in Fig. 2B). *Spirochaetaceae* played a critical role and was common between the two reactors, where the color of dark red indicated it was regulated by more microbial members and the large node size, conveying high betweenness centrality, indicates that *Spirochaetaceae* was always connected to other microbial members with the shortest paths. The other four members which were distinct between mesophilic and thermophilic processes, *Flavobacteriaceae*, *Methanocorpusculaceae*, *Ruminococcaceae* and *Methanomicrobiaceaei*, had concordant topological properties such as a smaller node size with a dark red color: These were regulated by a variety of microorganisms but rarely influenced others. Furthermore, more OTUs denoted with stars were observed at a high temperature. These nodes with stars were unlikely to influence other members owing to the low level of out-degree interactions.

The effect of key microorganisms on biogas or methane production

We compared two microbial interaction networks from mesophilic (37°C) and thermophilic (55°C) anaerobic microbial communities by using MetaMIS and identified key microorganisms (*Flavobacteriaceae*, *Xanthomonadaceae*, *Alcaligenaceae*, and *Nocardiaceae*) according to the topological niche. Meanwhile, we purified hundreds of strains from an anaerobic digester as potential candidates. Taking the family of *Xanthomonadaceae* as an example, we isolated a strain named *Xan* (Species) that has strong interactions with other microbes. BMP tests were performed to evaluate the effect of adding different concentration of *Xan* on biogas or methane production. Then, we conducted



Hydrolysis	
1	*p1: Porphyromonadaceae*
2	*p1: Spirochaetaceae*
3	*p1: Rikenellaceae*
4	*p1: Bacteroidaceae*
Acidogenesis	
5	*p2: Flavobacteriaceae*
6	*p2: Enterococcaceae*
7	*p2: Veillonellaceae*
8	*p2: Aerococcaceae*
Acetogenesis	
9	*p3: Erysipelotrichaceae*
10	*p3: Peptostreptococcaceae*
11	*p3: Syntrophaceae*
12	*p3: Acidaminococcaceae*
13	*p3: Desulfovibrionaceae*

Methanogenesis: Methanogens	
14	*p4: Methanotrichaceae*
15	*p4: Methanobacteriaceae*
16	*p4: Methanosarcinaceae*
18	*p4: Methanomicrobiaceae*
19	*p4: Methanocorpusculaceae*
21	*p4: Methanoregulaceae*
22	*p4: Methanospirillaceae*
26	*p4: Methanomassiliicoccaceae*
Methanogenesis: others	
17	*p4: Corynebacteriaceae*
20	*p4: Pseudomonadaceae*
23	*p4: Enterobacteriaceae*
24	*p4: Planococcaceae*
25	*p4: Coriobacteriaceae*

Combined pathways	
27	*p1,2: Clostridiaceae_1*
28	*p1,2: Clostridiaceae_2*
29	*p2,3: Lactobacillaceae*
30	*p1-4: Ruminococcaceae*
31	*p1-4:Prevotellaceae*
32	*p1-4:Lachnospiraceae*
33	*p1-4:Synergistaceae*
Desulfurization	
34	*deS: Syntrophobacteraceae*
35	*deS: Desulfobulbaceae*
36	*deS: Desulfobacteraceae*

Figure 2. Microbes with different topological niches under mesophilic or thermophilic conditions. The interaction networks identified at mesophilic (A) or thermophilic (B) temperatures. Nodes represent microbial families. The size of the nodes corresponds to their betweenness centralities. A larger node indicates higher betweenness centrality which has a large influence on the transfer of information through the network. The color of the nodes conveys the number of in-degree interactions, describing how many OTUs influence this node. The node shown in dark red connects the maximum in-degree nodes, i.e., 10. The node closest to the center of the network has the highest level of eigenvector centrality, a measure of the influence of a node in a network. Three nodes linked by a red dotted circle indicates the top three most influential OTUs. The top six are denoted inside an orange dotted circle. The pink arrow indicates an activate relationship, and the blue arrow indicates a repressive event. Nodes marked with an asterisk (*) have a very low level of out-degree interactions.

two laboratory-scale anaerobic digesters, which were 5-liter bench-top continuous stirred tank reactors (CSTR), to confirm the effect of *Xan* (#1 for 1.7×10^6 CFU/ml manure) on gas or methane production (Fig. 3).

In conclusion, the results showed that there was a significantly enhancement of gas (Fig. 3A) and methane (Fig. 3B) production by adding *Xan*. In the future, we will clarify the functional roles of key microorganisms by annotate the genome and microbial interactions. The research pipeline will be applied on pig manures of different farms within Taiwan in seeking for a universal keystone species.

Identification of metabolomics and methane production pathways in anaerobic digester

The metabolomics and proteomics data from anaerobic digesters under different operational conditions to confirm the detail chemical factors which were important in microbial communities to digest the carbon and nitrogen sources. Short-chain fatty acids (C3-C7) were detected by using GC-MS which indicates greater amount of smaller and shorter chain fatty acids were detected from 55°C swine manure anaerobic digester than 37°C condition (Fig. 4).

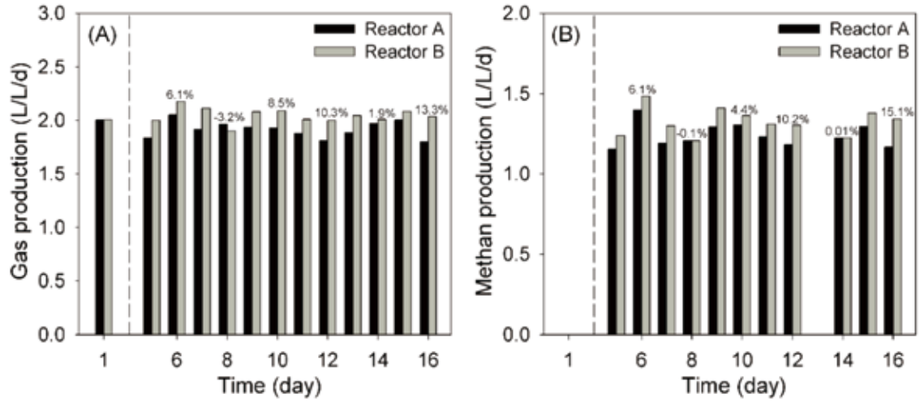


Figure 3. The gas (A) or methane (B) production after the addition of *Xan* (Species) (1.7×10^6 CFU/ml manure) in CSTR-type digesters.

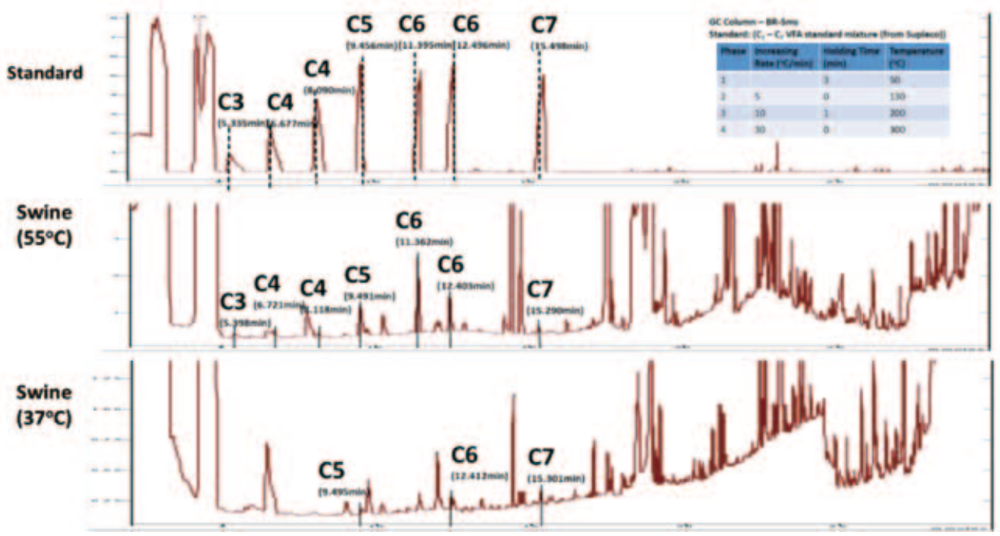


Figure 4. Chromatogram of standards and samples indicating short-chain fatty acids. Temperature program and conditions are indicated in the table above. 1st chromatogram indicates the standard mixture containing short-chain fatty acids (C3-C7) and the approximate time of elution detecting the VFAs; 2nd chromatogram indicates swine manure (55°C) and the approximate time of elution detecting the VFAs; 2nd chromatogram indicates swine manure (37°C) and the approximate time of elution detecting the VFAs.

Due to the metabolomics result, it was indicated that a higher temperature can generate a higher amount of short-chain fatty acid which was the precursor of methanogenesis to produce methane by methanogenic archaea. The metabolic pathway in methanogenesis phase under 37°C (Fig. 5A) and 55°C (Fig. 5B) anaerobic digesters were compared according to the proteomic data set. We noticed that the microbial diversity under 55°C was lower than 37°C. The identified proteins involved in methanogenesis phase were marked (stars) in Fig. 5, which indicated acetoclastic methanogenesis was the major process to produce methane at 55°C. On the other hand, proteins involved in both hydrogenotrophic methanogenesis and acetoclastic methanogenesis were identified from 37°C anaerobic digester which was consistent to the higher microbial diversity in mesophilic condition result.

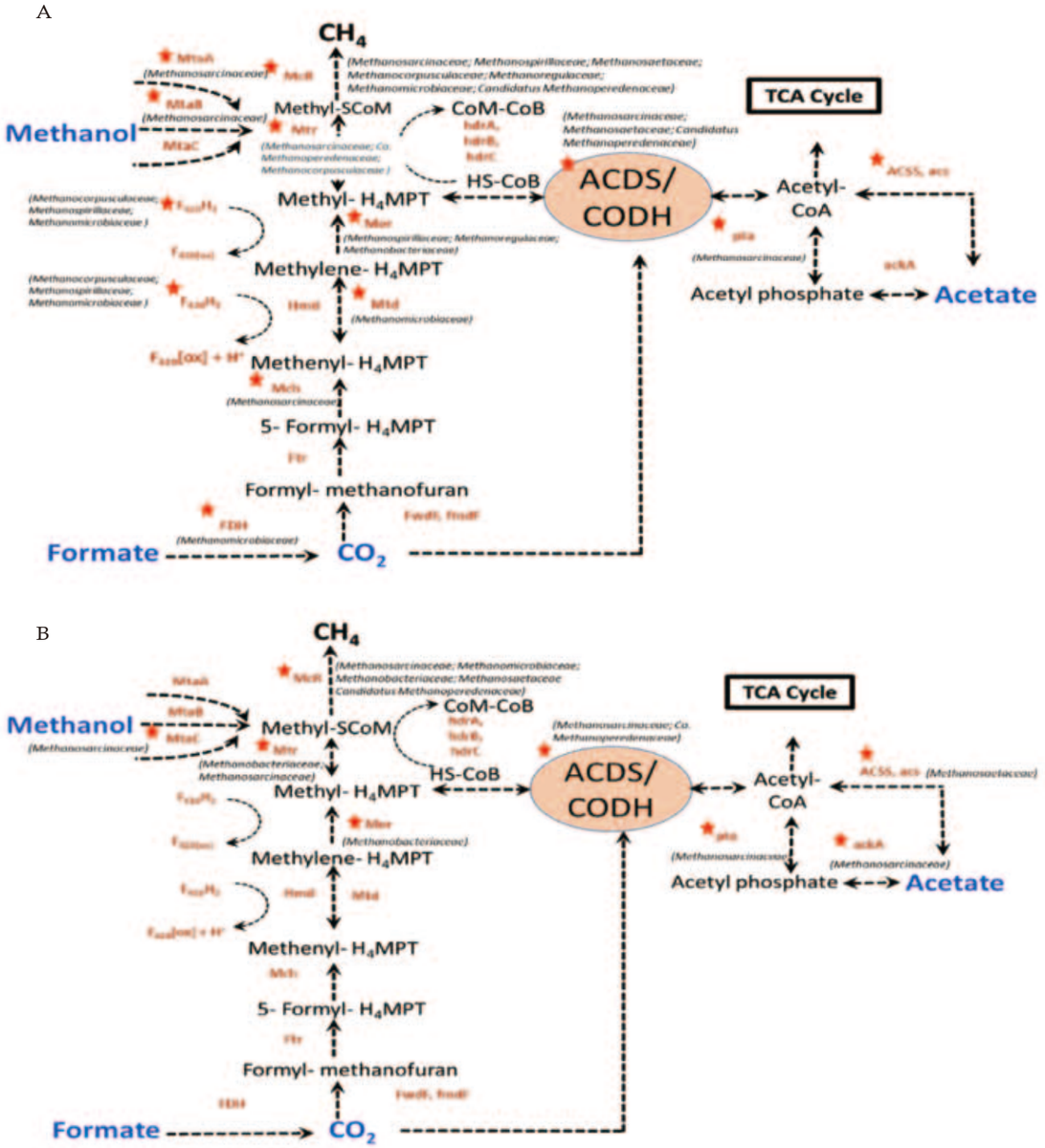


Figure 5. Summary of metabolic pathway in methanogenesis phase in the swine manure at (A) 55°C and (B) 37°C sample set. (Fonts in blue indicate the proteins/enzymes involved in the reaction; fonts in black indicate the metabolites)

Future Research Plan

In this project, we based it on the swine manure as substrate to operate the anaerobic digester for further detection of methane production. During these three years (2015-2017), we already optimized the operational conditions and tried to set-up the co-digestion system coupled with agricultural wastes, such as bamboo, orange, pineapple, and banana. In this project, we tried to investigate the interaction between microorganisms in this anaerobic digester. According to metagenomics organization, we proposed key microbes which may positively modulate the methane production. Lab-scale experiments already showed the positive results that key microbes in this study can stabilize the system and enhance the methane production at the same time. On the other hand, the metabolomics and proteomics analysis provide the comprehensive information to monitor the chemical reactions in anaerobic digesters. These bioinformatics results were based on the lab-scale anaerobic digester condition. In order to applicate to industry and animal farms in Taiwan, it should be scale-up to pilot-scale which can perform 1 to 10 tons of samples to obtain the operational factors that closed to the real field experiments. We propose that this data can provide a new strategy to monitor and modulate the operational conditions to obtain a higher methane production. We hope this project can provide the application potential in green-energy development.

Publications

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2. Shaw GT, Pao YY, Wang D: MetaMIS: a metagenomic microbial interaction simulator based on microbial community profiles. *BMC Bioinformatics* 2016, 17:488.
3. Shaw GT, Liu AC, Weng CY, Chou CY, Wang D: Inferring microbial interactions in thermophilic and mesophilic anaerobic digestion of hog waste. *PLoS One* 2017, 12:e0181395.
4. Wan-Ling Wu, Shu-Jung Lai, Jhih-Tian Yang, Jeffy Chern, Suh-Yuen Liang, Chi-Chi Chou, Chih-Horng Kuo, Mei-Chin Lai, Shih-Hsiung Wu. 2016. Phosphoproteomic analysis of *Methanohalophilus portucalensis* FDF1^{T} identified the role of protein phosphorylation in methanogenesis and osmoregulation. Scientific Reports. 6: 29013.
5. Shu-Jung Lai, I-Fan Tu, Wan-Ling Wu, Jhih-Tian Yang, Louis Y.P. Luk, Mei-Chin Lai, Yu-Hsuan Tsai and Shih-Hsiung Wu. 2017. Site-specific His/Asp phosphoproteomic analysis of prokaryotes reveals putative targets for drug resistance. BMC microbiology. 17:123.

Project Director: ***Shih-Hsiung Wu***

He received his Ph.D. in 1987 from University of Wisconsin, Madison USA. His research interest focuses on the structure-functional relationship of biomolecules including polyketides, polysaccharides and proteins and bacterial phosphoproteomics in environmental adaptation.
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Sub-Project PI, Co-PI:

Chu-Yang Chou, BRC, NTU | Suming Chen, BRC, NTU | Daryi Wang, BRC, AS

Development of Novel Thermoelectric Materials for Sustainable Energy

Project starting year: 2017
Hosting Institute: Institute of Atomic and Molecular Sciences, Academia Sinica

Research Objectives

The progress of thermoelectric technology relies on the development of materials that can effectively harness heat into electricity while considering the cost, health and environmental ramifications. This project focuses on the development of thermoelectric materials through discovering new material configuration such as nanostructures, composites and additives and understanding existing state-of-the-art thermoelectric material by looking into its fundamental properties using theoretical, computation and experimental tools.

Main Results to Date

Due to the high cost and limited efficiency of the thermoelectric devices, TE has still a long distance from meeting our current energy and decarbonization demand. How to enhance the efficiency and cut down the cost of TE devices has been the focus of worldwide TE research. Under the support of Center for Sustainability Science, a Thermoelectric Team has been established, which includes top-notch physicists such as Dr. M.K. Wu and Dr. M.Y. Chou. In the past few years, the team has demonstrated p-type TE materials such as $Bi_{0.5}Sb_{1.5}Te_3$, Zn_4Sb_3, and GeSbTe exhibiting ZT up to ~ 1.6. The idea to integrate aerogel into TE materials has been proven effective under M.K. Wu's supervision. Figure 1 shows the ZT of the n-type $Cu_{0.01}$-$Bi_2Te_{2.7}Se_{0.3}$ sample in black squares. While our starting material does not yet match the record value of ZT = 1 at 373 K in literature, the addition of Si aerogel pushes the ZT to record levels. ZT is found to be ~1.1 from 350 to 450 K, with the peak value of ZT = 1.12 at 425 K. An n-type PbTe with ZT~1.8 has been developed under the collaboration with China Steel Corporation. Our study also covers the layer-structured SnSe based compounds (SnSe, $SnSe_{1\pm X}$, $Sn_{1-X}Ge_XSe$), that act as a model material to enrich our fundamental understanding of thermoelectric properties (Figure 2).

In addition, a GST thin film with ZT>2.5 has been attained in K.H. Chen's laboratory, which currently is under rigorous confirmation and mechanism study (Figure 3). Ge-Sb-Te material system is a known compound in the realm of phase change memory applications wherein they are used as the active component in compact discs (CDs), blue-rays and RAMs for electronic devices. Since 2013, our group has started to look into this material's potential for thermoelectric applications. Recently, through thin film fabrication technology we have achieved a record breaking zT of 2.97 (±0.52) which arises from the high power factor value 54 (±9) μW/cm-K^2. (Figure 3a and Figure 3b) A high value of the power factor indicates that a TE device with this material can extract more energy from the temperature gradient generated. Through various advanced techniques such as synchrotron X-ray spectroscopy and diffraction, we

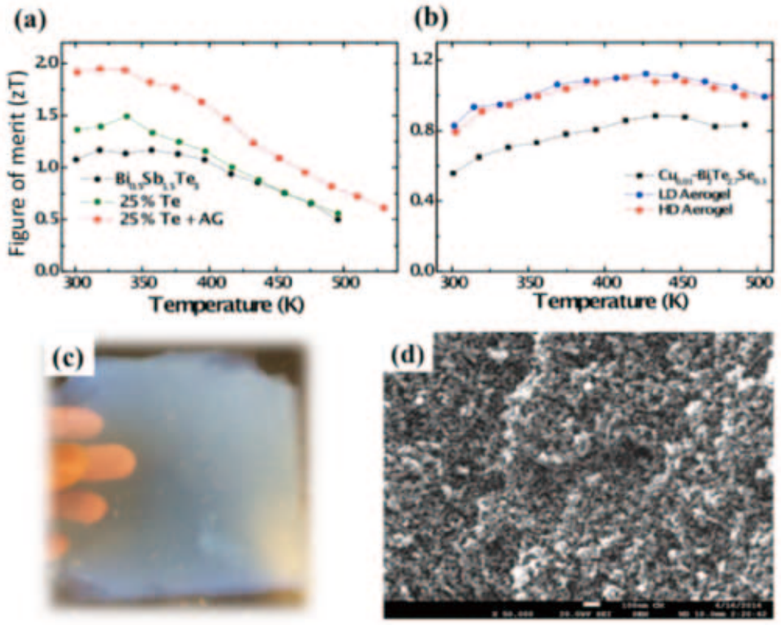

Figure 1. (a) ZT of p-type BiSbTe, with extra Te, and with extra Te+AG. (b) ZT of n-type CuBiTeSe, and with addition of AG. (c) Optical image of aerogel. (d) SEM image of the aerogel.

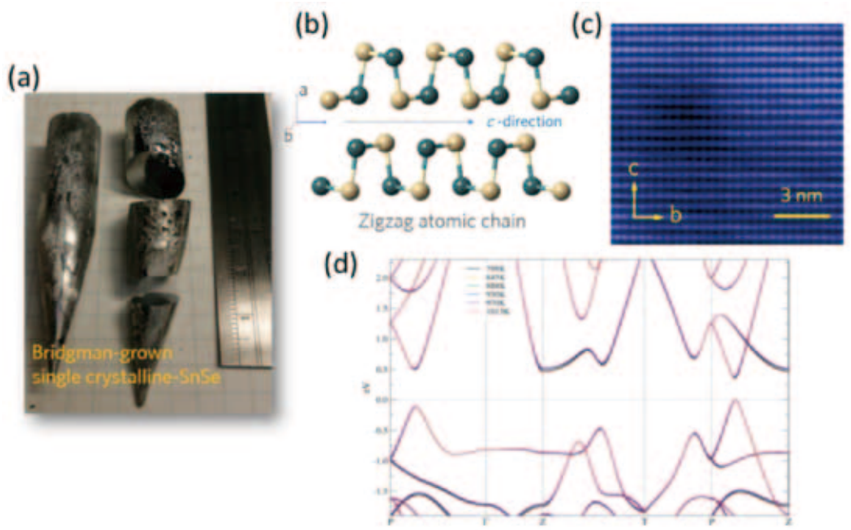

Figure 2. (a) Bridgman-grown SnSe crystals with the crystal direction along the (100) face. (b) Zigzag chains of Sn-Se atoms. (c) STM topography of SnSe (100) surface obtained at a bias voltage of 1.6 V and 200 pA constant current at 5 K. (d) Electronic band structures of the SnSe *Cmcm* phase obtained using DFT-PBE.

were able to probe and correlate the electronic and structural changes (Figure 3c) occurred in our film with temperature. The unique electronic transition, which causes a valence band shift, accompanied with a change in its effective mass, allows the material to access other electronic states and other carriers, consequently, a boost in the electrical conductivity while preserving the Seebeck coefficient value. Structurally, we discovered a unique distortion in the film's crystal lattice which is unusual for materials that have been assign to a cubic configuration. Through monitoring the film's diffraction pattern at elevated temperature, we observed that from a distorted cubic configuration the film transformed into a more ordered cubic system right about the point where we also observed the electronic transition. This development offers another insight towards the characteristic of this material system for future design.

Moreover, Skutterudites specifically $CoSb_3$ has been a model system in thermoelectric materials for more than a decade. Recently, our group stumbled upon a different material system related to this family. Co $(GeTe)_{1.5}$ has stirred interest within our group due to its good compatibility to the p-type nature of the Ge-Sb-Te. For a thermoelectric device to work efficiently, both a p-type and n-type semiconductor is needed. Combining Ge-Sb-Te and Co during the sputtering process and post-annealing treatment has open us up to a different material system closely resembling to the Skutterudite family above. Up to date, we have demonstrated a zT value of around 3 for this type of film. (Figure 4) Unlike the Ge-Sb-Te film above, we are still in the process of getting more information with regards to the origin of its superior thermoelectric performance. Nonetheless, this n-type film has shape up to be a promising complement to the thermoelectric performance exhibited by the p-type Ge-Sb-Te film.

Future Research Plan

Herein, we carry on the momentum in thermoelectric research to continue the following sub-projects: (1) New thermoelectric material development and

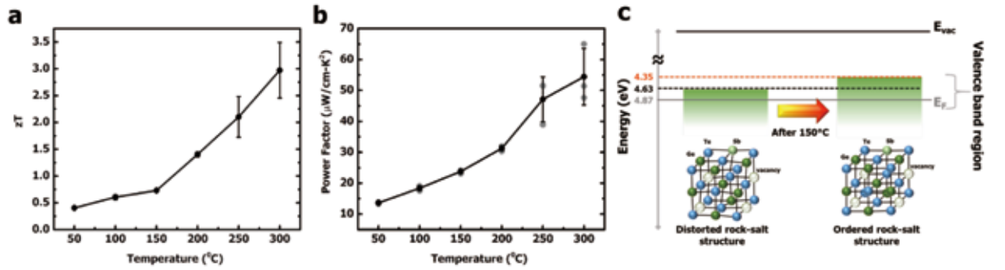

Figure 3. (a) Temperature-dependent figure-of-merit, zT and (b) temperature-dependent power factor of Ge-Sb-Te thin films with (c) schematic diagram describing the electronic transition occurring in our film during measurement.

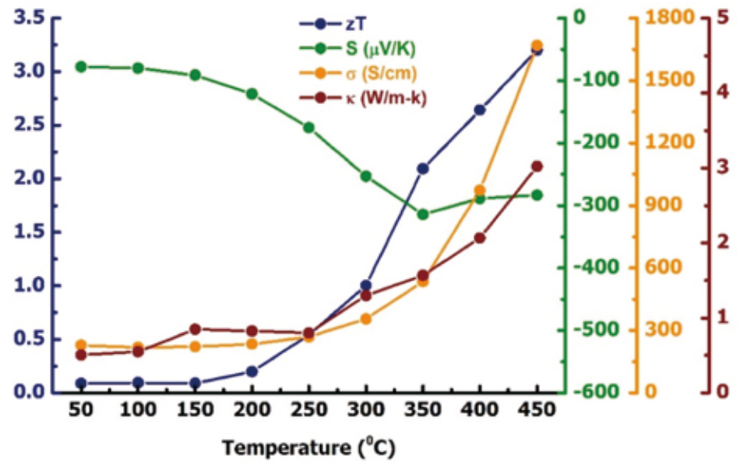

Figure 4. Temperature-dependent thermoelectric properties of Co-Ge-Te with Sb thin film.

single crystal growth of materials with layered and cage-like structures; (2) Effects of interfacial and nonlocal thermal conduction to thermoelectricity; (3) Development of thin films and low-cost thermoelectric materials; (4) First-Principles Calculations of the Physical Properties of Thermoelectric Materials. We also invite Dr. Raman Sankar, an outstanding crystal grower, to join the team. Under the new teamwork, fundamental studies such as the thermal transport, electrical transport, and thermoelectric behavior will be tackled experimentally and theoretically. Meanwhile, the materials synthesis approach will include novel structures, composites, and thin films and to explore earth abundant and low-cost TE materials. In this way, we hope to carry on the ongoing enthusiasm and make thermoelectricity a choice for sustainable energy in the foreseeable future.

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Project Director: ***Kuei-Hsien Chen***

Kuei-Hsien Chen is Distinguished Research Fellow and Director in IAMS. He has long experience in the synthesis and characterization of advanced materials with the aim for energy applications such as thermoelectric, photovoltaic, solar fuels, and lithium-ion battery. He is devoted to the development of earth-abundant and low-cost thermoelectric materials, one of the sub-projects in the SSRP project.
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Effects of environmental changes on rice growth and production in Taiwan

Project starting year: 2017
Hosting Institute: Agricultural Biotechnology Research Center, Academia Sinica

Research Objectives

Climate changes could affect agriculture through its effects on environmental conditions, such as drought, extreme temperature and flooding. In Taiwan, there were reports in recent years that environmental changes have resulted in a reduction in rice production and grain quality and an acceleration in the emergence of virulent rice pathogens. We have assembled a multiple institutional team to study the effects of climate change on rice crops in Taiwan. In the past three years we have solved the problem of bacterial blight disease by generating a new breed of rice that is pathogen-resistant and can identify an effective biocontrol agent against bacterial blight disease. In addition, we have made significant findings in the effects of heat stress on rice production and regulation of mineral nutrient utilization in rice. In the current proposal, we will address the problem of another important rice disease, the rice sheath blight disease caused by the fungal pathogen *Rhizoctonia solani*. In addition, based on our findings in the past three years, we will investigate the molecular mechanisms of heat stress tolerance and nutrient utilization and generate rice breeds that are more efficient in nutrient utilization. The project consists of six subprojects that cover the following topics:

- Subproject 1: Development of strategies to control the rice sheath blight disease caused by the fungal pathogen *Rhizoctonia solani*.
- Subproject 2: Analysis of transgenic rice expressing heterologous heat tolerance gene
- Subproject 3: Exploration of phosphate transport system to improve phosphorus use efficiency in rice
- Subproject 4: Improvement of nitrogen use efficiency in rice under climate change
- Subproject 5: Biofortification of metal micronutrients in rice
- Subproject 6: Generation of rice cultivars with improved nitrogen utilization

Main Results to Date

Rice sheath blight disease is caused by the fungal pathogen *Rhizoctonia solani*. We have isolated a novel strain of *Bacillus amyloliquefaciens*, designated ASB111, that has strong antagonistic activities against *R. solani*. By liquid chromatography-electrospray ionization-tandem mass spectrometry (LC-ESI-MS) analysis, three groups of compounds, including iturin, fengycin and surfactin, were found to be effective against *R. solani*. These results will be used in developing ASB111 as a viable agent for control of rice sheath blight disease. In addition, by screening NaN mutagenized rice populations, we have obtained two mutants that are highly resistant to *R. solani*. Genetic mapping is currently in progress to identify rice genes that are responsible for pathogen resistance.

We have produced transgenic rice expressing the Arabidopsis AtHsfA2 gene (pYC125). The result

indicates that heterologous expression of AtHsfA2 can induce the expression of heat shock protein in rice. Physiological experiments showed that the pYC125 transgenic rice seedlings had significantly higher thermotolerance.

In rice, a total of 13 plasma membrane-localized Pi transporters have been identified belonging to the *PHT1* family. We found that *OsPT1*, *OsPT7* and *OsPT12* were highly expressed in the late stage of flowering development. *OsPT7* and *OsPT12* were expressed in the flower specifically. In the rice cultivar *Indica* (9311) and *Japonica* (TNG67), highly expressed *OsPT1/7/12* were observed in different flowering development stages. *Eternal Tapetum 1* mutant (*eat1*) showed repressed expression of *OsPT7/12* compared to WT, indicating the correlation between Pi transport and tapetum cell death or pollen development.

We have utilized CRISPR-Cas9 to generate knockout mutants of *ZOS5-02* transcription factor, which will be used in molecular breeding of rice with improved nitrogen utilization efficiency.

We have obtained rice mutants with alternative Fe and Zn accumulation in seeds. Some of these mutants have defects on the formation of Fe plaque in the root that may interfere the uptake of nutrient especially P and other metal ions for growth and development. With the mutants isolated, we can for the first time examine the importance of Fe plague in Fe uptake.

We generated transgenic rice overexpressing NC4N, which is a key transcription factor in regulating nitrogen remobilization in plants. Two batches of NRT1.7p:NC4N:3' transgenic rice (*Oryza sativa* TNG67) were done. In the field trial, 4 transgenic rice of the first batch showed the increased tiller number under normal nitrogen condition (120kg N/ha) compared to TNG67 control, 2 of them are statistically significant. It suggested that NC4N transgenic rice had the potential for high yield.

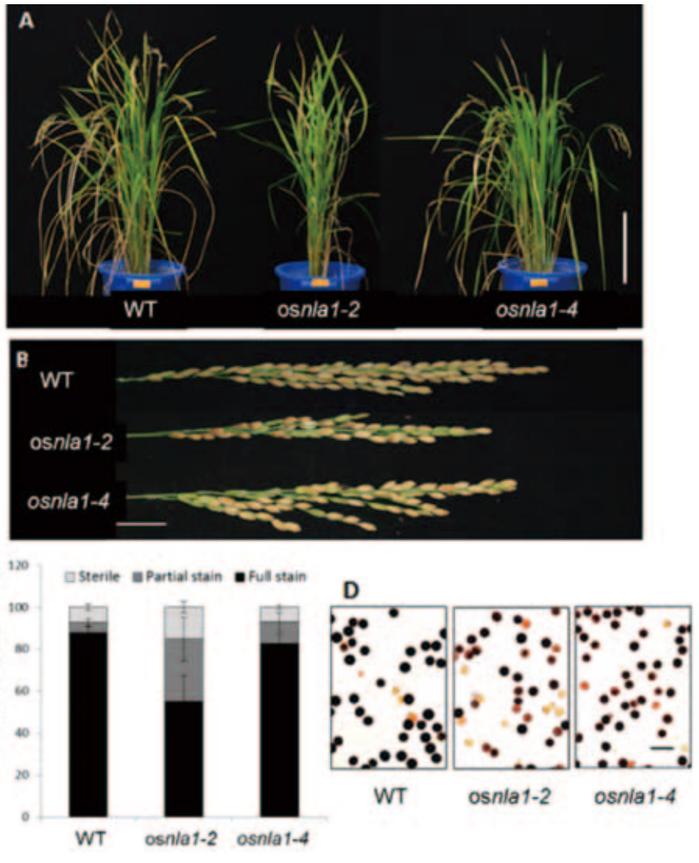

Figure 1. Phenotype of *osnla* mutants in the field
(A) Plant growth of the WT and *osnla* mutants at harvesting stage. (B) Panicles of the WT and *osnla* mutants at grain maturity stage. (C) Percentage of pollen fertility in *osnla* mutants. (D) Pollens stained with 1% I2/KI solution. Bars= 20cm (A), 2 cm (B), and 100μm (D).

In summary, we have made substantial progress toward solving the rice sheath blight disease by the identification of biocontrol agents from microbes and obtaining rice mutants that are resistant to the blight disease pathogen *Rhizoctonia solani*. The combination of biocontrol and resistant rice cultivars will greatly reduce loss of rice crop yield, and more importantly decrease the usage of pesticides by farmers. Furthermore, our studies of heat stress response and nutrient genomics and the physiology of rice will allow us to breed rice that is more tolerant to heat stress and more efficient in nutrient utilization. Cultivation of these rice cultivars will increase yields and reduce the usage of fertilizers by farmers.

Future Research Plan

We will perform field trials to investigate whether the putative anti-*Rhizoctonia solani* compounds are effective in preventing the rice sheath blight disease. We will also characterize the two mutants that are highly resistant to *R. solani*. Genetic mapping will be used to identify rice genes that are responsible for pathogen resistance. We will also use the rice mutants and the transgenic rice plants that we have generated to determine the molecular mechanisms of heat stress tolerance and nutrient utilization in rice.

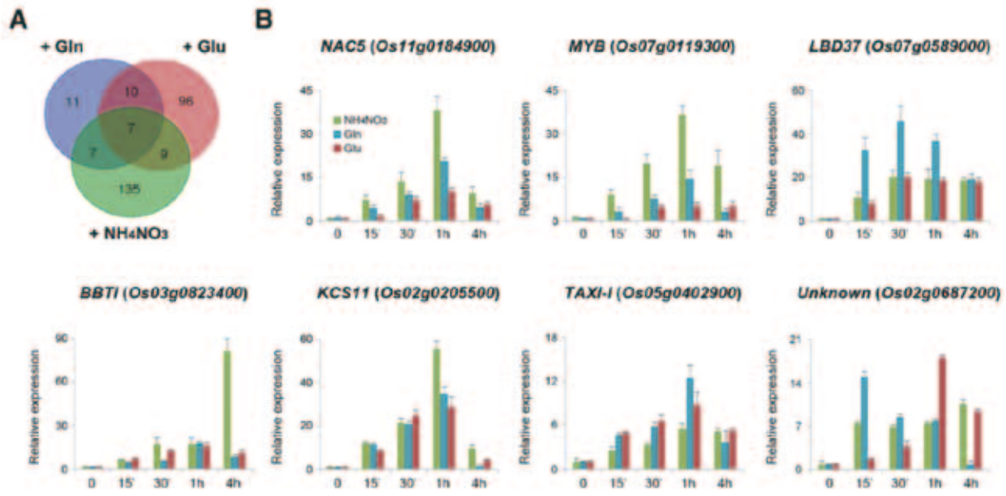

Figure 2. (A) Venn diagram showing the number of differentially expressed genes for treatments with glutamine, glutamate, and ammonium nitrate. (B) Quantitative RT-PCR analysis of *NAC5, MYB, LBD37, BBTI, KCS11, TAXI-I,* and an unknown gene.

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3. Chang T-S, Liu C-W, Lin Y-L, Li C-Y, Wang AZ, Chien M-W, Wang C-S**, Lai C-C (2017). Mapping and comparative proteomic analysis of the starch biosynthetic pathway in rice by 2D PAGE/MS. Plant Mol. Biol. 95:333-343. (co-corresponding author).
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Project Director: ***Ming-Che Shih***

Ming-Che Shih is a Distinguished Research Fellow of the Agricultural Biotechnology Research Center. His research focuses on plant responses to environmental stresses, application of omics technologies in sustainable agriculture and agricultural biotechnology. A major project in his lab is to explore microbial genomes for biocontrol agents against plant pathogens.
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Linking ecology to management for sustaining resources of coral reefs facing climate changes

Project starting year: 2015
Hosting Institute: Biodiversity Research Center, Academia Sinica

Research Objectives

The Kenting National Park (KNP), established in 1985, is the first national park to enforce conservation of terrestrial and marine diversity in Taiwan. Located in Southern Taiwan, the KNP have received a high increase of the local anthropogenic pressures over the last three decades, causing a profound degradation of the coral reefs in the area, as well as an erosion of the resources available for coastal communities. Combine this with the recent coral bleaching events and typhoons in the region, the result is a shift from coral to algae dominant (or other alternative taxa) of many sites around the KNP, precipitating the collapse of services provided by this ecosystem. Conciliating growing socio-economic demands with ecological conservation represents a challenge to sustain durably coral reefs. With the recent prevision on climate change, there is therefore an urgent need to build a resilient system which could help the coral reef in the KNP to face future environmental modifications.

Main Results to Date

In our study, a transdisciplinary approach including **environmental assessment, socio-ecological surveys, coral reef ecology**, and **ecosystem modeling** were adopted to identify keys levers and their potential impact on the overall state of the coral reefs in the Kenting National Park (KNP).

At the land, riparian forest and stream corridor could help maintain water quality before entering the coral reef nearby by reducing nutrients input through the absorption of nitrogen, phosphorus and sediments along the river banks. In contrast, pollution from the land-based sources have been demonstrated as one of the primary causes for coral reef degradation. As human populations expand at coastal areas, township development alters the landscape and thus increases runoff from land. It is an important issue to understand the relationship among the environment of the riparian forests, stream corridor, and the water quality of estuaries that have an effect on the fringing reefs nearby the township. We therefore evaluated current and historical impacts of human activities on marine environment around Kenting National Park (KNP), the relationship of stream corridor, water quality and stream biodiversity. Three main objectives, including (1) recording the water quality and aquatic animal assemblage among different rivers and seasons; (2) illustrating watershed altered by humans that affects the structure and function of stream ecosystems and the water provided to estuaries of the drainage; and (3) documenting condition of watershed along the stream and the important factors that maybe affect the fringing reefs. Results derived from this subproject was provided as input factors for scenario modelling.

Three main river systems, Baoli River (BR), Shinu

River (SR) and Gangkou River (GR) were surveyed between 2015 and 2017. Water quality and biological survey were conducted in every season. The physical condition of every river was evaluated by the modified Rapid Habitat Ecological Evaluation Protocol (mRHEEP) in the dry and wet season in 2015, and repeated in the following two years. The relationships among water quality (RPI), biological Index (FBI), and river physical factor (mRHEEP) were compared. Analysis of water quality showed no seasonal variation in every river. The BR, particularly the at the section of Longluantan Drain Ditch, was the highest polluted river among three river systems in the KNP due to the inputs of sewage from Henchun Township and village nearby. The SR close to the Kenting sewage treatment plant showed the middle area was polluted at the downstream section. The GR showed no sign of pollution due to low urban development along the catchment and river plain. Overall, the RPI, FBI, and mRHEEP showed that river habitats were better at the upper part of river than those of the middle or downstream areas, but poor conditions when the river runs by the villages, farms or military training base. No significant difference between the dry and wet seasons in these indices. The RPI, FBI and mRHEEP performed better in Gangkou River than the other two river systems in the KNP, suggesting that **human activities have a significant effect on the health of catchment and river plains, and thus, influenced the water quality input to the adjacent reefs in the KNP.**

The other impact of human dimension on the coral reef ecosystem is how human society utilized the natural resources, how does social-economic respond to people having to elaborate the conservation effort in protecting the coral reef, particularly under the impact of climate change. We used the choice experiments (CE) to build random utility model of the coral reef, with taking into account the attributes of recreation (number of tourists), ecological (living coral coverage (%) and biodiversity), and institutions (marine protected area (%), conservation foundation of coral reefs) in the KNP. Preference heterogeneity across different sites and respondents, and estimated the conservation values of the coral reefs on multiple scenarios were tested. In addition, the human impact reduction program including the diving and scuba diving tourists aspects toward the management strategy, and estimating the individual's preference and marginal willingness to pay (MWTP) for the impact reduction program, were built up. Finally, the issues of economic evaluation under climate change and human impact on coral reef ecosystem, estimating the relationship between climate factors and reef coverage, and estimating the conservation preference and MWTP for the KNP, were examined.

The empirical results of social-ecological analysis shows that: (1) The respondents would prefer to change the current state of the coral reef conservation and impact reduction in Kenting area; (2) For the coral reef conservation program, increasing living coral coverage to the health level, increasing biodiversity, improving the water quality to fit standard level, set a 75% limit of tourist quota a day from current number, and a lower conservation foundation of coral reefs, will increase the utility of all tourists visiting Kenting area; (3) For the reduction program of reef impact, the respondent would have a higher MWTP for the increasing the education training, and establishment the marine police, following by control the number of divers, setup the control of experience area, and take the boat to snorkeling point; (4) The heterogeneity preference of conservation program among the variety of tourists' social background, travel experience, and MWTP, which reveals the different conservation segmentation of the coral reef; (5) The respondents have the positive, significant preference and MWTP on the impact reduction program of the reef ecosystem were influenced by higher income, joined the conservation group, and the scuba diving tourists; (6) For the welfare estimation on impact reduction program of reef management, the best scenario was integrated program followed by institutional management and recreational control; (7) All respondents in Taiwan would support the potential coral reef conservation program towards climate change and human impact, and the respondents who have are younger, higher income, join the environmental NGO, and agree set new marine protected area would have a higher MWTP and marginal willingness to pay additional tax to the new program with coral reef conservation. The empirical results could help build up a reasonable budget allocation on the coral reef ecosystem, and design the possible management policy in the near future.

As the first national park, the KNP served not only as a tropical marine biodiversity hotspot but also embracing the consequences of overfishing, habitat destruction, and pollutions due to the unregulated fishing practice, unsustainable increasing of tourist numbers, and coastal development to meet the requirement of economic growth of the region as well as the country. Combined with recent coral bleaching events and typhoons in the region, these impacts have created a shift from coral to algae dominant (or other alternative taxa) around the KNP, precipitating the collapse of services provided by this ecosystem. Despite implementation of MPAs, many reefs within the KNP are now degraded. **Monitoring and documenting the impacts of natural and anthropogenic disturbances and finding potential solutions that could enhance the resilience of the coral reef is an urgent task to sustain the ecosystem service of the KNP to both domestic and nation needs.**

We, therefore, performed a global assessment of the state of the reef within the KNP. Over 100 reefs have been used to determine the pre-project state of the KNP reef. Following the initial assessment, 11 sites were selected along a gradient of environmental conditions and anthropogenic disturbances to cover most of the heterogeneity observed in KNP. Those sites were then seasonally surveyed to track the dynamics of the reef ecosystem in KNP and their responses to specific disturbances such as typhoons and bleaching events, in order to assess the resilience capacity of the KNP reef ecosystem. Ecological surveys confirmed that the benthic communities of the KNP were dominated by turf and macro-algae, and remained hard corals belonging to the stress tolerant species. Fish communities are dominated by small size individuals and characterized by low biomass of sessile invertivorous and piscivorous. **Both benthic and fish community surveys suggested that the coral reef in the KNP were begin constantly disturbed by many factors including overfishing.**

Finally, all the information from the terrestrial environmental assessment, social-ecological analysis, and coral reef ecology were then integrated into our ecosystem model built under python but based on the Ecosim with Ecospace (EwE) model. Our model covers 869.75 km^2 of land (620,25km^2) and sea (249,5 km^2), going beyond the limit of KNP in order to fully integrate the 4 watershed that affect the reefs in Kenting. This model allowed us to identify key areas of nutrient-based pollution entrance into KNP reefs, as well as anthropogenic activities contributing the most to those pollutions. In addition, our model shows **seasonality for some disturbances such as nutrient loads that can be related to rainy and monsoon season or typhoon events.** Consequently, our model suggests **the importance of implementing seasonal specific regulation in some areas of KNP, particularly on the western side of the Hengchung peninsula.** Furthermore, the model also identified the reef areas that need to be prioritized for management measures.

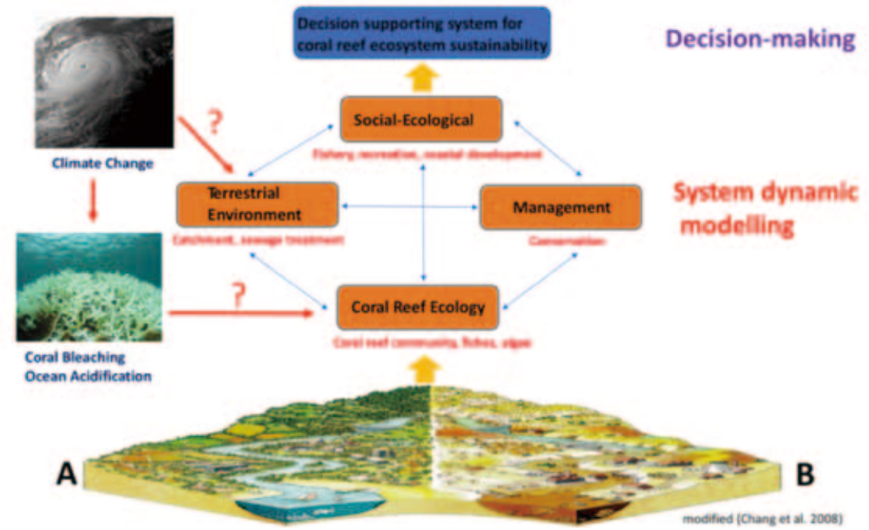

Figure 1. Conceptual framework and relationships among different systems (Social-ecological, terrestrial environment, coral reefs, and management) under the impact of climate change (typhoons, coral bleaching, ocean acidification). Terrestrial environment represented by catchment and sewage treatment, social-ecological analysis, and coral reef ecology, were studied and integrated into Ecosim and Ecospace to generate system dynamic models. The resulted scenarios are feedback to the final decision-making supporting system for policy making. **A**: health catchment system including well-maintained forest and clean river system providing pollutant-free freshwater into coastal marine ecosystem (e. g., coral reef); **B**: deforestation, and pollution derived from land-based sources cause degradation of coastal marine ecosystem.

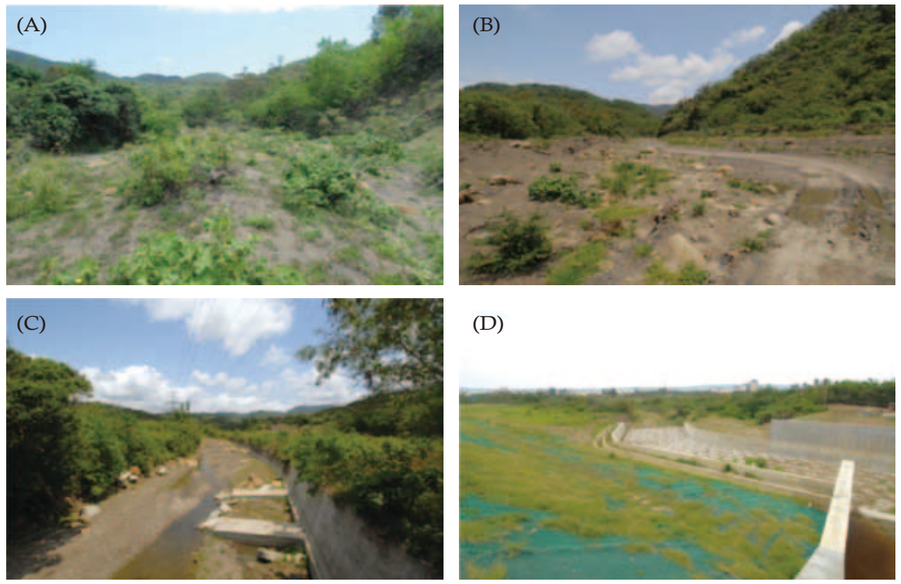

Figure 2. Examples of 4 different evaluated grades of river habitat qualities based on the range of scores (A) Excellent(≥80): Roughly maintain the natural state; (B) Good (≥60): Partly interference, but still maintains natural ecological functions; (C) Poor (≥30): Partly interference, part of natural ecological functions derogate; (D) Bad (<30): Suffered severe interference, natural ecological functions lost.

Table 1. The marginal willing to pay (MWTP) results for management scenarios under reef impact reduction.

Attributes & Levels	Hypothetical Future Scenarios		
	Institutional Management (I)	**Recreational Control (II)**	**Integrated Program (III)**
Control the number of divers	Setup the carrying capacity control for the snorkeling and scuba diving tourists	-	Setup the carrying capacity control for the snorkeling and scuba diving tourists
Control the area of experience diving	Setup the control mechanism for experience area	-	Setup the control mechanism for experience area
The way to the snorkeling point		Taking boat to the snorkeling point	Taking boat to the snorkeling point
Marine Police	Setup the marine police	-	Setup the marine police
Education Training	-	Increase education training before snorkeling and scuba diving	Increase education training before snorkeling and scuba diving
MWTP (NT$/trip/person)	471.4	283.4	754.9
95% Conference Interval (NT$/trip/person)	459.2-483.6	269.5-297.3	738.0-771.8

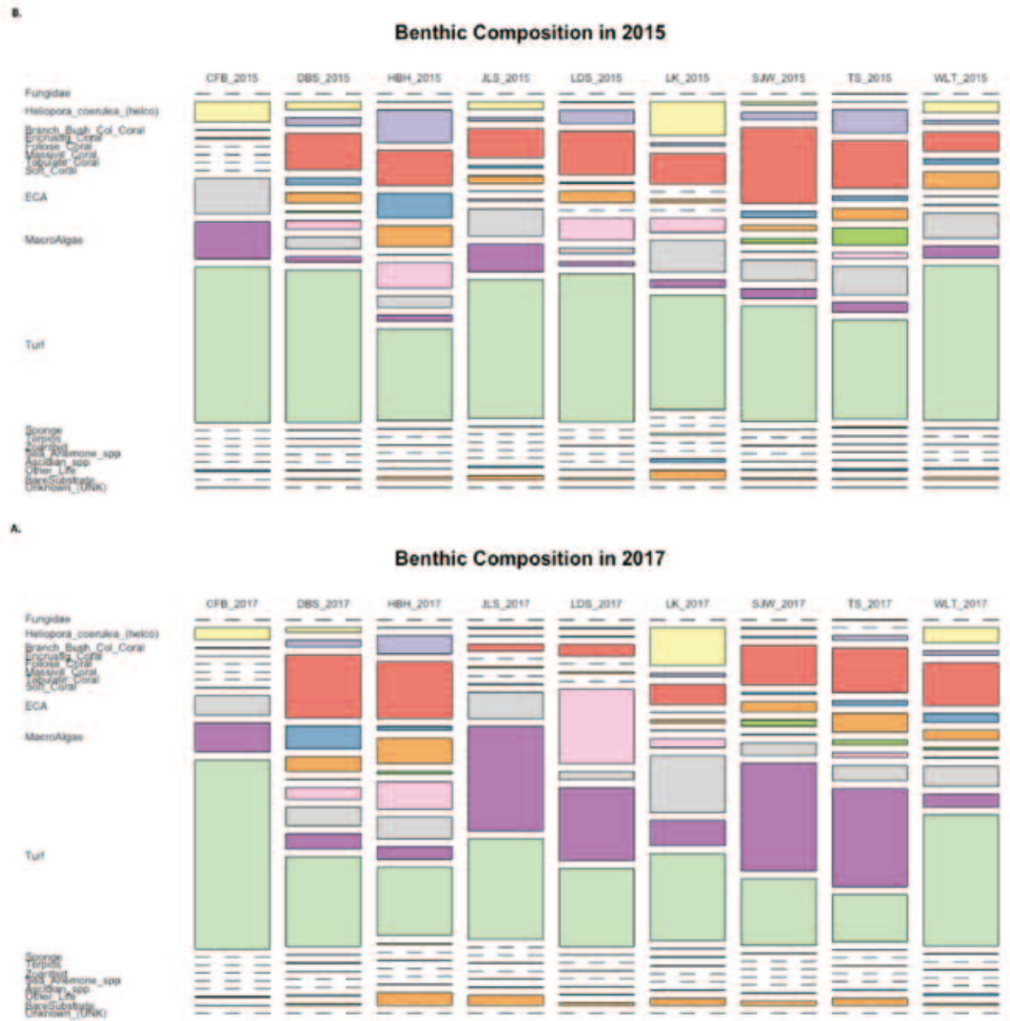

Figure 3. **Comparison of the benthic composition in major categories between 2015 (initial assessment; A) & 2017 (6 to 8 months after super-typhoon Meranti and Megi; B).** Hard coral contribution slightly decreased. Turf coverage also decreased but remain the major contributor of the benthic communities, while macro-algae increased by 4 times between 2015 (A) & 2017 (B).

Future Research Plan

1. Continue monitoring catchments of three river systems in the Kenting National Park, providing to the park authority the information for zoning and planning.
2. Continue to use the methods developed in our project to survey coral reefs in the Kenting National Park, at the meantime, to provide protocols to other marine part authorities, such as Marine National Park in Dongsha Atoll and South Penghu, for benthic community monitoring.
3. Apply the spatial system dynamic model developed from this project to generate scenarios under impact of climate change including typhoons, bleaching, ocean acidification, increase/decrease of local disturbances, and management modification (e. g., increase policemen, conservation fee, etc.) that can be implemented to Kenting National Park.

Publications

Ribas-Deulofeu L, Denis V, De Palmas S, Kuo C-Y, Hsieh HJ, Chen CA (2016) Structure of Benthic Communities along the Taiwan Latitudinal Gradient. PLoS ONE 11(8): e0160601.

Project Director: ***Chaolun Allen Chen***

Professor Chen studied biodiversity of coral reefs for 20 years. Dramatic increased of natural and anthropogenic disturbances impacting coral reef ecosystems brings Professor Chen to focus on resilience capacities of corals and reef-associated organisms along with local management to sustain coral reef ecosystems. Professor Chen aims to increase knowledge on functioning of coral reefs, from molecular to ecosystem scale using inter-disciplinary methods.
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Sub-Project 3

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Other members

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Integrated Multi-source and High-resolution Heat Wave Vulnerability Assessment of Taiwan

Project starting year: 2015
Hosting Institute: Research Center for Environmental Changes, Academia Sinica

Research Objectives

The overall goal of this thematic project is to evaluate heat vulnerability determinants in order to formulate corresponding heat adaptation strategies in Taiwan. The specific scope is to apply mature and innovative technologies to evaluating three determinants of vulnerability, namely, exposure, sensitivity, and response capacity, for the purpose of minimizing the health risks on hot days in Taiwan. A multidisciplinary team with experts on environmental, information and social sciences as well as public health is formed so that a holistic approach is taken in this trans-disciplinary research. Heat vulnerability assessment with fine resolutions is carried out as the basis for heat adaptation strategy recommendations.

Main Results to Date

This thematic project has concrete contributions in three aspects: Technology development, methodology development and research findings regarding heat-stress and heat adaptation, and social impacts. In terms of technology development, the IT tools for social media mining, activity locating, pollution sensing, and vision-based traffic analysis with fine tempo-spatial resolutions were developed. These technologies were applied to exposure assessment for heat-stress and $PM_{2.5}$, heat-health relationship evaluation, and response capacity survey in this thematic project.

The most ground-breaking development is the development of $PM_{2.5}$ micro-sensor device. This remarkable story is illustrated in Figure 1. A prototype of $PM_{2.5}$ micro-sensor device was successfully developed and evaluated based on the teamwork of environmental and IT scientists (upper and upper right part of Figure 1). In addition, with open-source codes and design, our team collaborated closely with a local maker community in Taiwan (the Location Aware Sensing System (LASS) community) which helped to improve the prototype. Furthermore, the technology has diffused into industry resulting in the production of "Air Box". Afterwards, the prototype developed in this project has been modified to more than 10 different versions to be applied in scientific research, pollution source screening, citizen's science, and pollution control strategy planning (right side of Figure 1). Currently, there are 3000 sensors in 30 countries with various modified versions shown in the air-pollution-sensing-network (https://pm25.lass-net.org/GIS/voronoi). The high interest and involvement of Taiwanese citizen's groups in this air-pollution-sensing-network have attracted the attention of various governmental agencies (lower part of Figure 1). These low-cost sensors have been installed in elemental schools and around industrial zones to assess ambient air quality and illegal emission sources, respectively. As a result, pollution sensing has been put into the National Forward-looking Infrastructure

Development Program. It is anticipated that the Smart City Planning promoted by the Executive Yuan will incorporate such low-cost sensors for city pollution sensing. This tool is also used by middle and elementary schools for environmental education. Moreover, two training courses were held to introduce the operation and potential application of this device for international scientists; several renown research teams including Harvard began to use these devices in their research. This is the best example of having impacts on society, policy-making, and international research arena with technology development (left and upper left of Figure 1).

In terms of methodology development and research findings regarding heat-stress and heat adaptation, besides scientific publications, the synergized knowledge of heat vulnerability integrated by system approaches for controllable behavior, environmental, and community factors has been presented in the interactive risk communication platform. Findings from all subprojects were consolidated to carry out heat vulnerability assessment and the extracted knowledge was converted in plain language for easy communication. Maps of exposure, sensitivity, and response capacity in township resolutions are presented in the platform. Among them, the exposure map is dynamically updated every 20 minutes based on the heat-stress-indicator observation network our team established in Taiwan in addition to CWB stations. This project provides solid evidence demonstrating that Wet-Bulb-Globe-Temperature (WBGT) is the most suitable heat-stress indicator. Figure 2(a) shows WBGT distribution at 11am of July 1, 2016 (the highest exposure during 2015-2017 study period) in Taiwan at township level; Figure 2(b) shows the WBGT averages of 7am-7pm on July 1, 2016 in Taiwan at township level. And Figure 2(c) presents WBGT distribution within 5km radius of weather stations in Northern Taiwan at 1pm, July 21, 2017 showing areas with WBGT in black-flagged range representing severe heat-stress exposure; the general public in the black-flagged areas should take immediate actions to avoid high WBGT exposure.

In addition to real-time presentation of WBGT distribution, 48-hour forecast for the heat-stress-indicator is also presented in the risk communication platform as an early warning system. Options for selecting different townships are provided so that the updated exposure, sensitivity, and response capacity of the selected township can be shown in a real-time fashion in this platform to evaluate the vulnerability extent of this township. Based on the findings of response capacity evaluation, a simple web-survey is offered in the platform which can be filled out by any interested individual to assess his/her own response capacity level. Ways to enhance his/her response capacity are provided aiming at reducing health risks due to direct exposure (heat-stress) and indirect exposure (air pollution) on hot days. The knowledge provided in this platform can be applied in environmental education, healthy behavior promotion, pollution control, community resilience enhancement, and heat warning system establishment. We wish to disseminate the heat vulnerability knowledge to the general public with this platform to reduce the overall heat-related health risks.

In terms of social impact, besides the aforementioned $PM_{2.5}$ micro-sensors, through interactions in various meetings, our research findings were provided to governmental authorities to influence the formulation of heat adaptation strategies aiming at reduce health risks from heat stress and air pollution. Most importantly, the crucial impact is to provide solid scientific evidences for establishing a heat warning system in Taiwan. Interactions with Central Weather Bureau (CWB), Department of Environmental Protection of Taipei City Government, and Ministry of Labor regarding establishing a heat warning system have been going on for three years. The heat warning system is the most effective heat adaptation strategy worldwide. Currently, only temperature is used as the heat indicator for the heat warning system. This project provides solid scientific evidences that WBGT is a better heat indicator than temperature alone. WBGT considers four important parameters of heat stress by human experience, namely, temperature, humidity, solar radiation, and wind speed. WBGT monitoring in households and communities around Taiwan, WBGT forecast with weather forecast models, WBGT exposure-health relationship evaluation, and suitable WBGT heat warning threshold exploration are all valuable outcomes of this project to form a solid foundation of WBGT heat warning system. CWB has considered to establish a WBGT heat warning system based on these scientific evidences. Moreover, Department of Environmental Protection of Taipei City Government and Ministry of Labor have been seeking for the assistance of our team to assess the WBGT exposure of the general public and workers, respectively, in order to establish a proper heat warning system for Taipei citizens and workers in Taiwan based on WBGT. This reaches the ultimate goal of this thematic project: Assisting in government authorities to formulate heat adaptation strategies to reduce health risks due to heat stress under the trend of climate change.

In summary, based on multidisciplinary collaboration, our team not only have scientific publication, but also accomplish innovative technology transfer for PM2.5 micro-sensor, knowledge dissemination on heat vulnerability and health risk reduction, and societal impacts on heat warning system establishment and PM2.5 citizen's science. Our efforts have been recognized by international renown teams with the aforementioned outstanding achievements. Overall, this project indeed fulfills the expectation of the Sustainability Science project, i.e., to apply scientific findings of cross-disciplinary collaboration in order to provide problem-solving solutions to tackle the challenge faced by society under the threat of climate change!

Figure 1. The collaboration between environmental scientists and information scientists (upper right corner) in this thematic project (upper part) has developed $PM_{2.5}$ micro-sensors (right) which have significant impacts on various governmental agencies (lower part), Taiwan society (left), and international research arena (upper left corner)

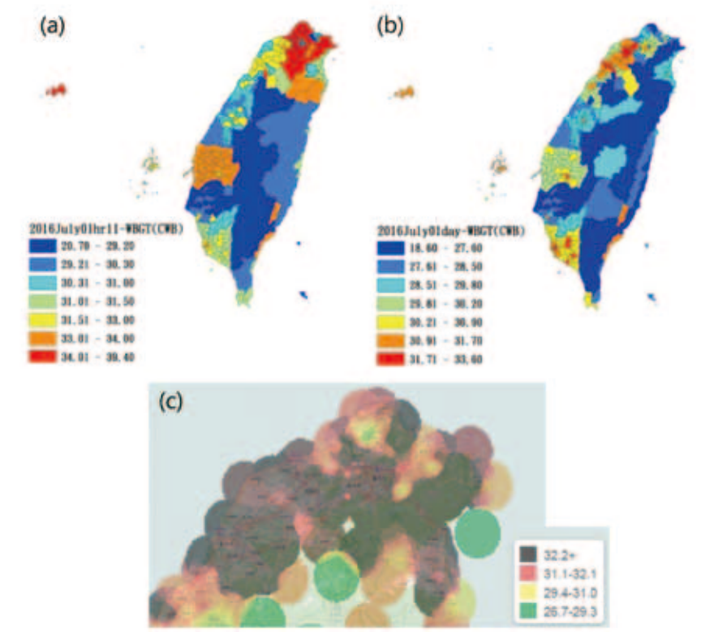

Figure 2. Real-time WBGT exposure map in the risk communication platform based on observations of CWB and RCEC stations (a) at 11am on July 1, 2016 (the highest exposure during 2015-2017 study period) in Taiwan at township level; (b) 7am-7pm average on July 1, 2016 in Taiwan at township level; and (c) within 5km radius of weather stations in Northern Taiwan at 1pm, July 21, 2017 showing areas with WBGT in black-flagged range representing severe WBGT exposure

Future Research Plan

We will continuously work together with the Central Weather Bureau, Department of Environmental Protection of Taipei City Government, and Ministry of Labor to assist in establishing a heat warning system based on WBGT in Taiwan. Additionally, we will keep improving $PM_{2.5}$ micro-sensors and apply these devices in researches in the fields of environmental sciences, human exposure assessment, indoor air quality, and environmental health sciences. We will also promote the application of the $PM_{2.5}$ micro-sensor devices in smart city planning and citizen's science.

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Project Director: ***Shih-Chun Candice Lung***

With academic training in atmospheric science and public health, Dr. Shih-Chun Candice Lung has focused her research on environmental health sciences, which investigates environmental mechanisms, pathways, and factors affecting public health. She has taken an integrated approach to link pollution source characteristics and atmospheric chemistry with human exposure and adverse health effects. Her research also expands to evaluate societal impacts of environmental and climate change and to explore adaptation strategies to reduce such impacts.
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A Blueprint for Healthy Aging: Determinants and Prevention of Frailty and Depression in Elderly

Project starting year: 2015
Hosting Institute: Research Center for Environmental Changes, Academia Sinica

Research Objectives

Frailty is an important intermediate toward disability in the elderly. High prevalence of disability in the elderly population will increase the social and medical burden to society. Our PPG aims to contribute to the understanding of frailty pathogenesis and social and physiological determinants as well as designing and testing lifestyle management approach for frailty prevention and regression. The ultimate goal is to provide direction and solution to geriatric syndrome prevention and management. A multidisciplinary team has been organized with experts in geriatric medicine, epidemiology, nutrition, rehabilitation, social science, and economics.

Main Results to Date

This thematic PPG has not only contributed to the understanding of frailty etiology and discovery of physical, lifestyle, and social determinants; but also developed and validated an effective low-cost home-based intervention protocol for frailty and pre-frailty management. The information discovered by our PPG has already been used and disseminated for geriatric cares.

With regard to frailty etiology, we found one medication effect (JAG 2016), two mid-life risk factors and several co-existing factors. We observed an interesting medicinal beneficial effect from a calcium-channel blocker (CCB). Prevalence of hypertension is very high in elderlies (JAG 2016). It is over a 90 percent chance for an individual to eventually develop hypertension. Among four major lines of anti-hypertensive medications (diuretics; beta-blocker; angiotensin converting enzyme inhibitor, ACEI; and calcium channel blocker, CCB), CCB usage is associated with lower odds of frailty compared to other anti-hypertensives. This finding is novel and may have significant implication on antihypertension medication choice for frailty management.

Elders with diabetes, arthritis, and big waist circumference/less muscle mass, and poor sleep quality are more likely to have frail status than otherwise. These conditions can be used for screening and preventing frailty. Among these factors, "less lean mass" and "large waist circumference" are also mid-life risk factors for predicting future development of frailty in old age. Therefore, training to build lean muscle mass and to maintain proper waist line throughout a person's lifespan should be advocated for healthy longevity.

To facilitate the understanding of the pathogenesis of geriatric syndromes, we study the relationship between frailty and depression through analytical epidemiology research, examining the effect of the co-occurrence of frailty and depression on mortality in the elderly. The results confirmed 3 hypotheses: (1) the co-occurrence

of frailty and depression resulted in higher mortality compared with frailty only; (2) individuals with both conditions had a lower probability of reversal than those with single conditions; and (3) a reciprocal relationship exists between depression symptoms and accumulation of deficits. This study may be among the first to use a longitudinal design addressing these 3 hypotheses.

It has long been recognized that dietary quality is associated with geriatric syndrome. However, most of the previous focus was on protein intake level. We are able to provide Protein AI (adequate intake) estimate for the first time for the elderly in Taiwan and discovered that the protein recommendation in the Taiwan Food Guide is not sufficient to prevent frailty for those with a caloric intake less than 1500 calories a day. This information has been adopted into the Taiwan DRI (Dietary Recommended Intake) revision in 2017. In addition, using reduced rank regression, we discovered a dietary pattern inversely associated with frailty (JAG 2017). Individuals with more phytonutrient-rich plant foods (vegetable, fruit, whole grains, nuts/seeds) and drink (tea), omega-3 rich deep-sea fish, and other protein-rich foods such as shellfish and milk have a lower chance of being frail. We applied the prudent diet principle extracted from this dietary pattern along with findings in the literature to design a dietary intervention protocol and demonstrated efficacy in reversing frailty state and geriatric depression. On the other hand, providing soy protein alone does not have this beneficial effect (APJCN 2018). The results of this trial point out the importance of a holistic approach.

Furthermore, combining the above dietary intervention method with a multi-facet physical training protocol (for strength, flexibility, balance and endurance), we designed and carried out a personalized (fitting the individual's needs), home-based exercise and nutrition intervention project in outpatients of the Miao-Li Ministry of Health and Welfare Hospital. We were able to demonstrate efficacy to improve dietary intake, physical performance, and frailty score. Most of the previous studies adopted hospital or center-based approach which cannot influence elders who are not willing to travel to the hospital on a routine basis. To the best of our knowledge, our study is the first of this kind, i.e. adopting a low-cost home-based approach. It can be readily adoptable by community-based hospitals and clinics.

Social capital has been deemed as one of the protective factors against frailty development. Our PPG explores the potential mechanism of social capital on frailty and mortality, considering the mediation of frailty and reverse-causality in the association between social capital and mortality. The results revealed that the social participation and supports can significantly prolong the elders' survival time, but such protection would be diminished by the level of frailty. In other words, the best way to invest social capital for health needs to be earlier in ages, just like Pitera keeping people younger looking before wrinkles appear. The protective effect of social participation and its reciprocal association with frailty should be considered for disease prevention.

In line with this social capital theory, our government has step by step developed geriatric care centers throughout communities in Taiwan, aiming to have at least one center in each village or Li (里). However, in these settings, they are lacking guidelines on how to provide healthy meals and how to guide elders to eat healthy at home. Following the success of our lifestyle intervention program, Health Promotion Agency of the MHW has provided a three-year grant for us to transform our dietary intervention contents into one which fits into the meal planning and group activities for settings such as elderly care community centers. A 12-center community-based trial is ongoing and will provide final results by the end of 2019.

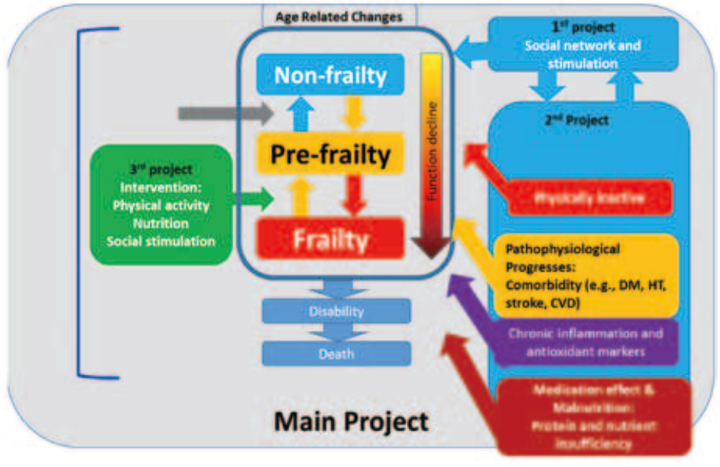
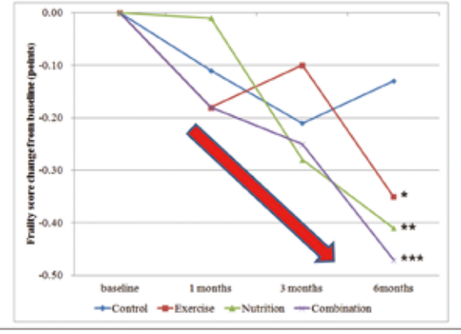


Figure 1. Integrations among projects of frailty

Overall speaking, our PPG has identified mid-life risk factors and precipitating/co-existing factors of frailty (physical, mental and social), differential anti-hypertensive medication effects on frailty status, and frailty-associated dietary pattern. This information has been used to design intervention protocols in clinical settings which demonstrate effectiveness for frailty regression. PIs of this PPG have been invited to deliver message/information derived from our PPG in various geriatric conferences and training sessions. Extensions of our PPG are underway through funding from governmental health agencies and serving as expert panel members for various policy and strategy making committees.

Figure 2: Possible mechanism for CCB protection on frailty



Compared to control group, the exercise, nutrition, and combination groups showed significant improvement in frailty score change from baseline.

$^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$

	Compared with control group, intervention groups change from baseline (95% CI)			*p* for
Time	Exercise (*n*=79)	Nutrition (*n*=83)	Combination (*n*=77)	intervention × time interaction
Baseline				< 0.001
1 month	-0.06 (-0.24, 0.11)	0.10 (-0.08, 0.28)	-0.07(-0.25, 0.11)	
3 months	0.11 (-0.07, 0.29)	-0.06 (-0.24, 0.11)	-0.03 (-0.21, 0.15)	
6 months	-0.23 (-0.41, -0.05)*	-0.28 (-0.46, -0.11)**	-0.34 (-0.52, -0.16)***	

Figure 3: Intervention effect of lifestyle approach on change of frailty score

Future Research Plan

◊ To develop the proper indicators of social frailty among the elderly in Taiwan

◊ To model the trajectories of social, mental, cognitive and physical frailties

◊ To investigate the impacts of multi-dimensional frailties on the mortality and social burden

◊ To follow participants and to investigate the progression/transition of frailty syndrome.

◊ To investigate the association between frailty syndrome, dementia, and mortality risk.

◊ To analyze the cost-effectiveness of nutritional and/or physical intervention for frailty elderly.

◊ Referencing our findings, to advocate proper intervention protocols for frailty management/prevention in clinical settings as well as in the communities in order to enrich the service contents of the Long-term Care Services Act.

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Enhanced GEMTEE (General Equilibrium Model for Taiwan Economy and Environment) for IAM Framework-An Integrated Computable General Equilibrium Model and Database for Appraising Policies toward Sustainable Development.

Project starting year: 2015
Hosting Institute: Institute of Economics, Academia Sinica

Research Objectives

Facing the intensified challenges from climate change, urbanization and the rapid ageing population, achieving sustainable societies in Taiwan will require an understanding of the life-supporting nature of water, energy, and food systems and how to maintain the balance among them. The major purpose of this project is to extend the GEMTEE (General Equilibrium Model for Taiwanese Economy and Environment) for integrated assessment of climate change impact and policy response at the regional context. With continuous collaborations from the experts in ABARES (Australian Bureau of Agricultural and Resource Economics and Sciences), we completed an ex-ante assessment of adaptation and mitigation policies that considers the impact on overall economy and employment, as well as on industry, energy demand, water use, greenhouse gas emission, government finance and income distribution.

Main Results to Date

The study involved three phases. **In the Year 2015**, context for the assessment was established by the regional-based GEMTEE comprised of four sub-modules that address human, food, water, and energy dimensions respectively in conjunction with a population dynamic module for long-term baseline forecasting. **In the Year 2016**, climate change impact vulnerability analyses in cardiovascular diseases, crop production, and household energy consumption were conducted under the four climate scenarios (RCP 2.6, 4.5, 6.0, 8.5 of ICPP AR5) provided by TCCIP. Socioeconomic and demographic scenarios of GEMTEE were then integrated with climate impact vulnerability analyses at the regional level towards the year 2060. The results are reported in Table 1. **In the Year 2017**, ex-ante policy impact assessments of climate change adaptation and mitigation were conducted using references from budgetary data and EPA's greenhouse gas emission goals to promote the transition to a climate-resilient economy. The results are reported in Table 2.

Our research results show that:

1. In the health sector, comparing with the mean in the base period (1992-2015), 1% increases in the average summer temperature will increase the total annual medical expenditures for cardiovascular disease by 1.371%. The death toll from cardiovascular diseases will rise due to climate change and aging population, and will later affect the working-age population growth. n the short term (2016-30), the health impacts due to both climate change and aging population will lead to a 0.582% decline in real GDP each year, while in the long term (2030-60) real GDP decreases by an average of 1.771% to 1.964% each year.

2. In the agricultural sector, climate change and temperature rise are harmful to Taiwan's crop yield, and will lead to an average of 0.027% to 0.483% annual losses in crop production from 2021 to 2060. Using GEMTEE, the total losses can be measured in terms of annual real GDP. In the short term (2016-30), the real annual GDP loss is -0.049% to -0.117%, while in the long term (2030-60) the real GDP decreases by an average of 0.024% to 0.080% each year.

3. Household energy consumption in Taiwan will also be affected by climate change and population aging because the temperature in fall and winter will become warmer. We found that changes in household energy consumption will cause no change in real GDP in the short term, and a slight increase of 0.0053% in the long term.

4. To sum up, in the short term, the annual losses from climate change induced impact on health, agriculture, water and energy demand on Taiwan's real GDP is about 0.61% to 0.67%, while in the long term real GDP decreases by an average of 1.41% to 1.80% each year. This will respectively result in a short-run loss of 0.80% and a long-run loss up to 2.37~4.32% in employment. At the sectoral level, the health impact from warming is the major driving force to trigger the real GDP losses, followed by water shortage and a decline in agricultural productivity. Job losses are also mostly due to health-related labor productivity loss.

5. According to 2012-2017 budget data of DGBAS, Taiwan government already invested NTD 45 billion per year in climate change adaptation. Our policy simulation results suggest that public investment in adaptation can lead to an annual increase of real GDP from NTD 21.1 up to 56.5 billion and 80,000 to 140,000 employment opportunities, which can be translated into a reduction of climate change damages and jobs saved. However, climate change adaptation will likely increase water demand and CO2 emission and thus adversely affect the environment.

6. Based on the climate change mitigation targets under the Greenhouse Gas Reduction and Management Act enacted in 2015, the implementation of mitigation actions will bring in a direct economic cost of NTD 23,000 per ton of carbon reduced and lower our total factor productivity by 1 percent. Our policy simulation results suggest that this can lead to indirect losses in real GDP from NTD 217 billion up to 219 billion. However, climate change mitigation will likely reduce water demand and CO2 emission by 1.83~2.33% and 1.44~2.12% respectively and thus benefit the environment in the long run.

To sum up, this project focuses on climate change impact and policy assessment based on the integrated modeling and data collected from four sectors. The results suggest that the government should pay due attention to demographic changes from rapid ageing and low fertility; integrate TCCIP climate scenario information, refine the CO2 emission baseline from the bottom-up; compare the financial costs and short- to long-term consequences of implementing adaptation and mitigation measures; understand the synergies and conflicts between different policy measures as the basis to communicate with different related agencies; and finally to develop the best portfolios of measures that aim to design the sustainable development pathway for Taiwan.

Table 1. The impact of climate change on Taiwan's real GDP, labor demand, CO2 emission and water demand.

	Short term (2016 - 2030)				Long term (2046 - 2060)			
	RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5	RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
				Real GDP (%)				
Health	-0.5827	-0.5820	-0.5820	-0.5820	-1.8727	-1.7707	-1.9640	-1.8780
Agriculture	-0.0493	-0.0907	-0.0987	-0.1173	-0.0240	-0.0267	-0.0213	-0.0800
Energy	-0.0007	-0.0007	-0.0007	-0.0007	-0.0053	-0.0053	-0.0053	-0.0053
Total	-0.6140	-0.6147	-0.6620	-0.6727	-1.8420	-1.8807	-1.8107	-1.7980
				Labor demand (%)				
Health	-0.8377	-0.8388	-0.8386	-0.8388	-2.3674	-4.2674	-3.9703	-4.2007
Agriculture	0.0505	-0.0196	-0.0225	-0.1171	-2.3674	-2.3283	-2.3211	-2.3143
Energy	0.0002	-0.0651	-0.0660	-0.0651	-2.3674	-2.3666	-2.3380	-2.3385
Total	-0.8018	-0.8019	-0.8020	-0.8012	-2.3674	-4.3159	-4.3133	-4.2715
				CO_2 emission (%)				
Health	-0.8387	-0.8373	-0.8373	-0.8373	-2.1667	-2.3033	-2.2847	-1.9767
Agriculture	0.0267	-0.3380	-0.4020	-1.0140	0.1153	0.1407	0.1520	0.2853
Energy	0.0000	-0.3540	-0.2267	-0.3533	0.0027	0.0827	-0.0153	0.1153
Total	-0.8160	-0.8147	-0.9133	-0.9213	-1.9933	-2.1500	-1.8960	-2.0173
				Water demand (%)				
Health	-0.6447	-0.6447	-0.6447	-0.6447	-2.2453	-1.9640	-2.0780	-2.5687
Agriculture	-0.0107	-0.1713	-0.1993	-0.4453	0.0427	0.0460	0.0567	0.0860
Energy	-0.0020	-0.1553	-0.1373	-0.1567	-0.0027	0.0240	-0.0007	0.0327
Total	-0.6493	-0.6507	-0.7073	-0.7180	-2.3100	-2.1640	-2.1713	-2.2313

Table 2. The effects of adaptation and mitigation programs on key economic indicators.

Item	unit	Adaptation (normal)	Adaptation (aggressive)	Mitigation (2016-2020)	Mitigation (2021-2030)
Real GDP	million NT	21,140.59	56,565.35	-318,822.88	-216,976.68
	%	0.15	0.40	-2.23	-1.52
Water demand		136.26	231.90	-423.54	-333.37
	%	0.75	1.27	-2.33	-1.83
CO_2 emission	ton	1,114.61	2,444.15	-5,299.65	-3,596.98
	%	0.45	0.98	-2.12	-1.44
Labor demand	Person	84,158	140,858	-2,189	-18,076
	%	0.77	1.29	-0.02	-0.17
Production value	million NT	139,230.75	223,548.03	-695022.99	-598,208.47
	%	0.40	0.64	-1.99	-1.71

Future Research Plan

Climate change is the greatest challenge for the sustainable development of human society. Burning fossil fuel also produces fine particles ($PM_{2.5}$) that are hazardous to human health. The use of renewable energy and the development of the green energy industry can decrease both carbon dioxide emissions and $PM_{2.5}$ output that helps reduce climate change impacts and protect human health. However, during the process of decommissioning nuclear power plants, there might be a transition period when Taiwan will heavily depend on coal-fired power plants, resulting in an increase of $PM_{2.5}$ production. Therefore, our future research will address the major issues in climate change and environmental governance: evaluation on the transition of sustainable governance from energy, social, political, regulatory, behavioral, macro and micro perspective. We will also explore the linkage of industrial planning with $PM_{2.5}$ emission from various sources and the related socioeconomic cost of $PM_{2.5}$ emissions.

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Project Director: ***Ching-Cheng Chang***

Research Fellow in the Institute of Economics at Academia Sinica and Professor of Agricultural Economics at National Taiwan University. Her recent work focused on integrated assessment of climate change impact and policy response, decision making of climate risk management, modeling of food-energy-water nexus, and household food consumption and dietary changes related to food and nutrition security policies.
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Knowledge and Technology Transfer

Seminar/Conference

In 2017, Center for Sustainability Science (CSS) held 5 seminars and 4 conferences as domestic platforms for promoting the knowledge and technology transfer. All researchers/experts of different fields in the research groups conducting CSS research programs were invited to join seminars for establishing the partnership network in strengthening collaborative capacity.

The Center conferences were held for those completed projects to share the outcomes and results with all possible stakeholders. Representatives from governmental departments, universities and industrial companies were invited to participate and to provide their suggestions which are supposed to strengthen the capacity in further comprehensive application of the research results in the future.

IRDR (Integrated Research in Disaster Risk) –
the challenge of natural and human-induced environmental hazards

Introduction

The first Integrated Research on Disaster Risk, International Centre of Excellence (IRDR-ICoE) was established in Taipei in November, 2010 at Academia Sinica (AS), and incorporated into the Center for Sustainability Science (CSS) in 2012. Under CSS's full support, ICoE-Taipei serves as an international interdisciplinary platform for 1) promoting integrated research comprehensively on disaster risk from both the natural and social science perspectives, 2) building an international partnership network of disaster reduction research, and 3) sharing the practical experiences in Taiwan among disaster early warning / responding / preparedness and preparation via international training courses, workshops and Advanced Institutes.

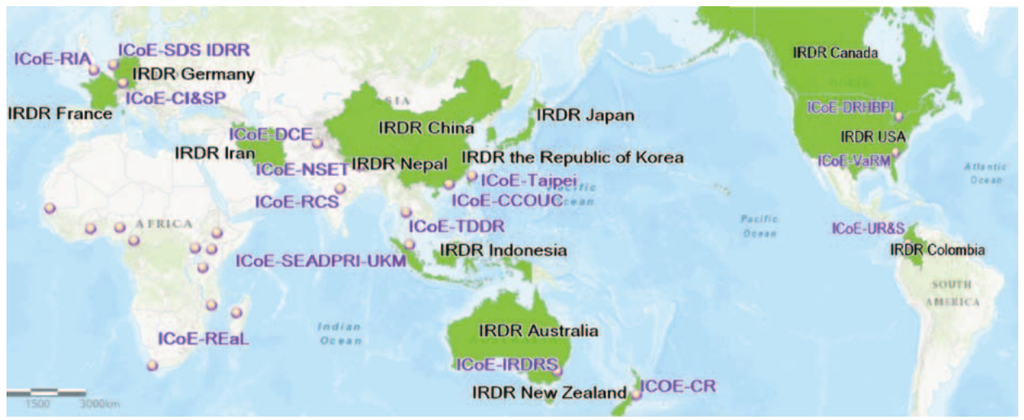
Integrated Research on Disaster Risk (IRDR) is a decade-long, international interdisciplinary research program initiated and sponsored by the International Science Council (ISC, the International Council for Science, ICSU and the International Social Science Council, ISSC merged in July, 2018 to form the International Science Council) in partnership with the United Nations International Strategy for Disaster Reduction (UN-ISDR). It is a global initiative seeking to address the challenges brought by natural disasters, mitigate their impacts, and improve related policy-making mechanisms.

To meet its objectives, the IRDR has identified 4 core projects as 4 Working Groups entitled "The Assessment of Integrated Research on Disaster Risk (AIRDR)", "DATA", "The Forensic Investigations of Disasters (FORIN)", and "The Risk Interpretation and Action (RIA)". Those working groups of experts from diverse disciplines from the Science Committee of IRDR formed to formulate new methods in addressing the shortcomings of current disaster risk research. For strengthening the capacity in promotion and implementation of IRDR's 4 working groups, the IRDR Science Committee has decided to set up a number of International Centres of Excellence (ICoE) around the world to provide regional and research foci for the IRDR and help attain the program's overall aims and objectives. There are currently 16 ICoEs and 13 National Committees (NCs) all over the world.

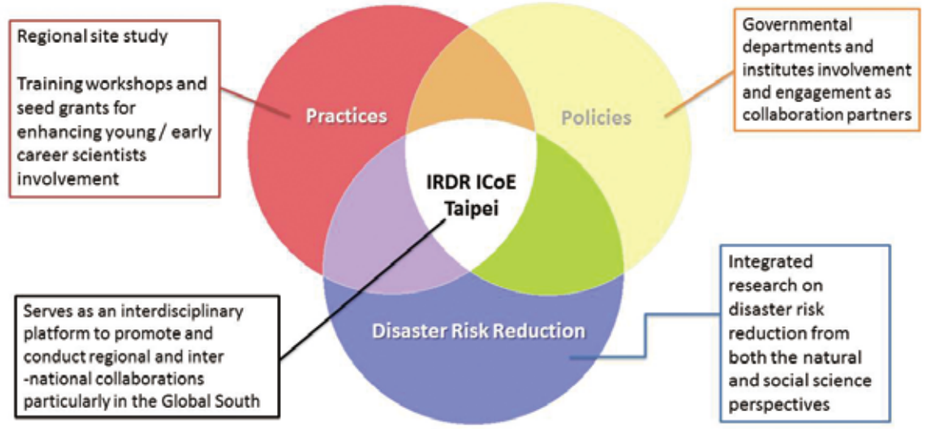
The tasks of the ICoE-Taipei include,

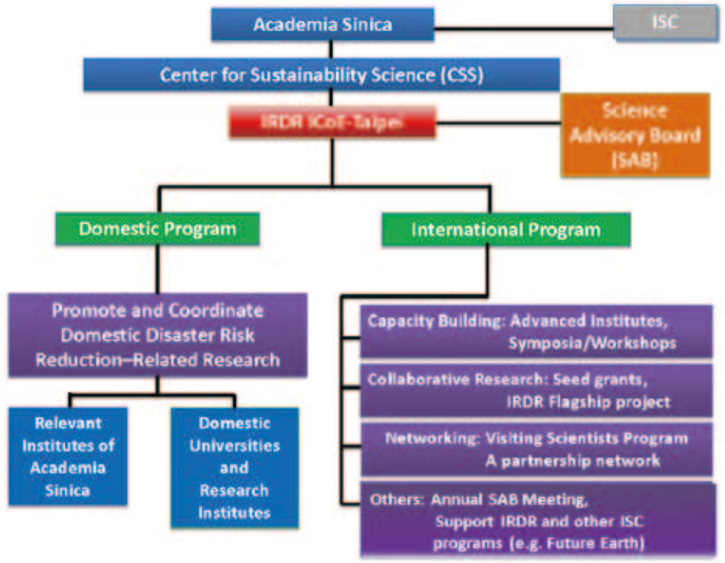
◊ Exchange of scholars between research institutes
◊ Exchange of ideas and information
◊ Collaborative research and regional site study
◊ Education and training for young scientists
◊ Establish a partnership network of disaster reduction research
◊ Conduct international and domestic collaboration

IRDR ICoEs and IRDR NCs Map



Source: IRDR website (http://www.irdrinternational.org/who-we-are/membership/)





IRDR ICoE-Taipei Scientific Advisory Board (SAB) Meeting was set to be held annually for obtaining suggestions in strategic directions and future plans. The SAB members are all from international/ academia reputable organizations and with great experiences in international collaboration, the ICoE-Taipei has actively participated in IRDR events and annual Science Committee Meeting.

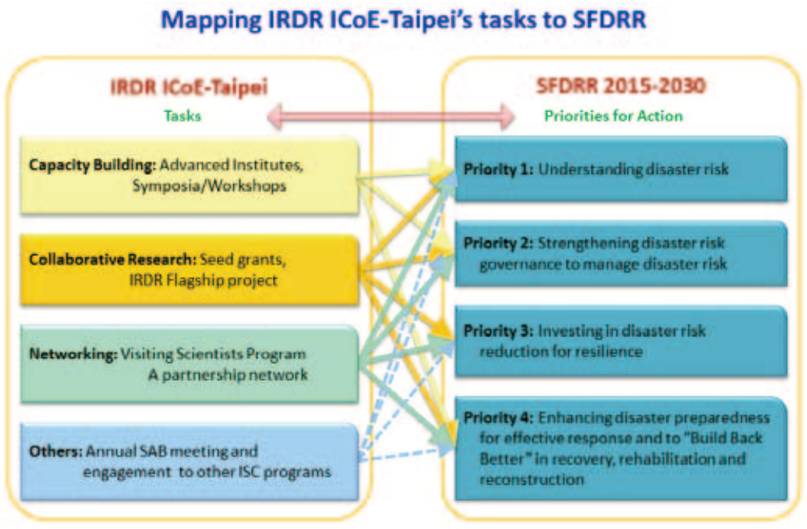
Last IRDR ICoE-Taipei SAB Meeting held on 26 JAN, 2018 at Taipei, Taiwan

We have invited all SAB members including the new elected members to join the meeting for early engagement. And we also invited Dr. Cheikh Mbow (Executive Director of START International) and Dr. Mei-Yin Cho (Vice President, Academia Sinica, Taiwan) as important guests to join the meeting.

Participated 18th IRDR Science Committee Meeting held on 20th-21th NOV, 2017 at Tokyo, Japan

Participated 19th IRDR Science Committee Meeting held on 15th-16th APR, 2018 at Beijing, China

Since the Sendai Framework for Disaster Risk Reduction 2015-2030 (SFDRR) has been endorsed by the UN General Assembly and adopted globally in the world, which emphasizes managing the risk of small-scale and large-scale, frequent and infrequent, sudden and slow-onset disasters caused by natural or man-made hazards. The causes and impacts of disaster events are generally complex. Thus it's essentially important for the IRDR ICoE-Taipei to design and implement effective practices to reduce disaster risks via interdisciplinary collaboration among different aspects. With worldwide vision, ICoE-Taipei has worked hard in strengthening the involvement and promoting regional networking for devoting into the SFDRR Priorities for Action.



Participated Global Forum on Science and Technology for Disaster Resilience 2017, on 23th – 25th NOV 2017, at Tokyo Japan
ICoE-Taipei has presented Taiwan experiences in disaster recover implementation at the priority 4 "Build Back Better" discussion section.

Participated 2nd Asia Science & Technology Conference for Disaster Risk Reduction held on 17th-18th APR, 2018 at Beijing, China
During the conference, the progress of SFDRR implementation has been reviewed by experts from diverse disciplines, ICoE-Taipei has shared the suggestions and experiences.

International Advanced institute/ Training Workshops

The center of ICoE-Taipei very much emphasizes on capacity building for countries in Southeast Asia. We organized different training workshops (Advanced Institutes) particularly for younger/ early career scientists and provided them with seed grants for initiating regional DRR theme projects especially within the Global South.

Since 2012, we have held five Advanced Institutes (i.e., training workshops) as following:

1) "Forensic Investigations of Disasters, **AI-FORIN**" (March, 2012),
2) "Data for Coastal Cities at Risk, **AI-DATA**" (October, 2012),
3) "Regional Networking", "Sustainable Urbanization", "Disaster Risk Reduction (DRR) and Loss Mitigation (LM), **AI-DRR & LM**" (April, 2015),
4) "Knowledge-based Actions for Disaster Risk Reduction, **AI-KBA**" (April, 2017), and
5) "Disaster Risk Reduction with Systems Approach for Slow-Onset Climate Disasters, **AI-SOCD** on Air Pollution, Sensors, and Big Data" (July, 2017).

With travel subsidy to cover the expenses of flight and accommodation, the center has supported and encouraged more than 150 young/early career scientists/ researchers from over 20 nations worldwide to join these 5 AIs since 2012.

IRDR ICoE-Taipei AIs & Training Workshops participants networking Map

Hereafter we describe two Advanced Institutes held in the year of 2017 in more details.

"Advanced Institute on Knowledge-Based Actions for Disaster Risk Reduction (AI-KBA)", 17th-21th APR, 2017

The importance of knowledge-based action has long been recognized for its cross-cutting linkage among key stakeholders such as scientists, policy makers, emergency responders and practitioners. However, in practice, how to take effective DRR knowledge-based actions requires out-of-box thinking and strategic practices. For disseminating the successful experiences achieved in Taiwan to IRDR communities, the intensive training workshop, "Advanced Institute on Knowledge-Based Actions for Disaster Risk Reduction (AI-KBA)", had been successfully held at Academia Sinica, Taipei, Taiwan from April 17th to 21th, 2017.

It was sponsored by IRDR ICoE-Taipei in partnership with ISC ROAP and National Science and Technology Centre for Disaster Reduction (NCDR), Taiwan. The main objective of the workshop was to provide the participants with the best practices, enhanced understanding, skills, and practical knowledge to apply systems approaches on DRR knowledge-based actions.

Advanced Institute on Knowledge-Based Actions for Disaster Risk Reduction (AI-KBA)" held on 17th-21th APR, 2017 at Taipei, Taiwan. There are around 20 participants from 8 countries from the Southeast Asia region participated in the workshop.

"Advanced Institute on Disaster Risk Reduction with Systems Approach for Slow-Onset Climate Disasters (AI-SOCD) — Air Pollution, Sensors, and Big Data", 10th-14th JUL, 2017

Air pollution has been seen as one of the major root causes of slow-onset climate disasters. Large-scale air pollution events can be transported hundreds of kilometers and have a significant impact on many countries and regional climate. Additionally, air pollution, especially aerosols, greatly contributes to human health risks. However, the application of these technologies requires a stronger multi-disciplinary collaboration among scientists from different fields and also from different countries. Applying systems thinking and systems approach to link environmental monitoring, information technology, and public health research is essential for the monitoring and detection of such disastrous events, which is the foundation for formulating disaster preparedness practices to better manage disaster risks.

To address this concern within the region, the intensive training workshop, "Advanced Institute on Disaster Risk Reduction with Systems Approach for Slow-Onset Climate Disasters (AI-SOCD) — Air Pollution, Sensors, and Big Data", had been successfully held at Academia Sinica, Taipei, Taiwan on 10th to the - 14th July 2017. The AI emphasized to provide young to mid-career practitioners, researchers and policy makers in Asia and the Pacific region with enhanced understanding, skills and practical knowledge to apply systems approaches in DRR research focusing on Air Pollution, Sensors, and Big Data.

"Advanced Institute on Disaster Risk Reduction with Systems Approach for Slow-Onset Climate Disasters (AI-SOCD) — Air Pollution, Sensors, and Big Data" held on 10-14 JUL, 2017 at Taipei, Taiwan. There around 20 participants from 11 countries in the Southeast Asia region were selected to participate in the AI.

Seed Grant Projects

For each of the Advanced Institutes, we also have initiated "Seed Grant Projects" to encourage participants of AIs and training workshops to start their research and establish the foundation for regional collaboration in the near future.

This research grant program aims to foster and enhance trans-disciplinary disaster risk reduction projects within the region of Asia and the Pacific. The focus is to develop a stronger interface between science, policy and practice, by promoting effective collaboration between scientists and local authorities to identify information and knowledge gaps in disaster risk reduction and emergency preparedness and to introduce science and technology filling the gaps with better knowledge-based actions. IRDR ICoE called proposals for the one-year research grant programme with limited finances of USD 15,000 support for collaborative inter-disciplinary research that falls within the areas of interest.

AI-KBA Seed Grant Projects:

And there are 4 projects are granted for one year (NOV, 2017– NOV, 2018). The grantees will be requested to submit a formal research report to IRDR ICoE-Taipei and ISC ROAP by the end of execution duration.

Project Title	Earthquake Resilient Communities in ASEAN Region: A Transdisciplinary Approach
Research team	5 members of participants from Malaysia, Pakistan, Singapore, and Thailand / 7 Collaborators from Australia, Germany, and Malaysia / 2 Consultants (Advisors) from Malaysia and Taiwan.
Expected outcomes	1. Disaster resilient index for sub-district 2. Indicator for freshwater ecological impact induced by disaster 3. Advisory report for policy implication on mainstreaming DRR into development planning 4. Geo-Portal on Multi-Sector Disaster Resilient 5. Synthesis report covering state of knowledge and strategies

Project Title	Developing Indicators for Resilience of Micro Small Medium-Sized Enterprises (MSMEs) in Asia
Research team	3 members of participants from, Malaysia, New Zealand, and Thailand / 3 Collaborators from Malaysia, Nepal and Thailand
Expected outcomes	EXPECTED OUTPUT: 1. As set of Indicators for measuring resilience of MSMEs 2. One (1) Scopus Indexed Paper and a full report EXPECTED OUTCOME: The proposed research is expected to have implications as follows: 1. The proposed MSMEs indicators can contribute towards national agenda for localizing Sendai Framework for DRR; 2. The proposed MSMEs indicators will assist in self-monitoring thus lessen the government role and responsibility; and 3. The proposed MSMEs indicators that contribute to MSMEs resilience towards natural disaster will better suit the MSMEs particularly in the context of Nepal and Malaysia.

Project Title	Developing Humanitarian Aid Distribution Process Information System Framework for ASEAN Countries
Research team	6 members of participants from Malaysia, Philippine, and Thailand
Expected outcomes	1. Novel theories/New findings/Knowledge -Develop a humanitarian aid distribution process information system framework for disaster management stakeholders 2. Research Publications -The finding of the research work will be presented in one international conference or to be published in one Scopus indexed journal and will submit one report. 3. Specific or Potential Applications -A disaster management team competency framework for humanitarian aid distribution process for the ASEAN level. -Potential mobile application for humanitarian aid distribution process in order to strengthen the relationship among disaster management team which is government sector and non-government organizations (NGOs) in helping the disaster victim.

Project Title	Evidenced Based analysis of Flood Risk Management and Social Vulnerability --- A System Approach in Sakon Nakhon Province, Thailand
Research team	2 members of participants from Thailand / 4 experts from Japan, Malaysia, Singapore, and Taiwan
Expected outcomes	The present study will take and holistic approach to take effective DRR knowledge-based action to develop a community based resilience framework and recommendations for policy framework and decision making. Followings are the brief expected outcome of project: - Developing comprehensive indicators through System Approach for social vulnerability assessment and flood resilience. - Developing a Local level framework for flood resilience through Multi Stakeholder approach. - Mapping of critical drivers for flood risk and vulnerability at various level of the social system. - System based Recommendations for community based resilience framework for the flood prone community.

AI-SOCD Seed Grant Projects:

And there are 4 projects are granted for one year (MAR, 2018– MAR, 2019). The grantees will be requested to submit a formal research report to IRDR ICoE-Taipei and ISC ROAP by the end of execution duration.

Project Title	The influence of biomass burning on high concentration of $PM_{2.5}$ in selected areas in Southeast Asia
Research team	3 members of participants from Malaysia and Thailand / 1 Consultants (Advisors) from Taiwan.
Expected outcomes	1. $PM_{2.5}$ compositions in the biomass burning prone areas 2. The impact of $PM_{2.5}$ and its composition especially during biomass burning episode to human health. 3. Suggestion on mitigation procedures on how to reduce risk from $PM_{2.5}$ from biomass burning episode.

Project Title	Building urban resilience: A systems approach to analyzing social and personal health risks of jeepney commuters and drivers to $PM_{2.5}$ in Metro Manila, Philippines
Research team	2 members of participants from Philippine/ 5 Consultants (Advisors) from Philippine and Taiwan.
Expected outcomes	1. Quantified personal exposure of commuters and drivers 2. Preliminary assessment of potential health risks 3. Preliminary design of statistical analysis of the socio-economic data on exposure and vulnerability 4. Preliminary design of cost benefit analysis 5. Preliminary policy and program recommendations for consideration related to the jeepney modernization program

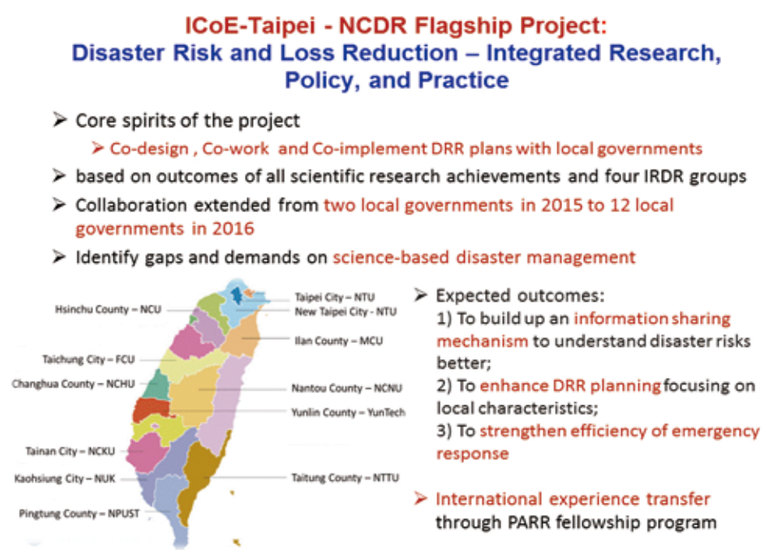
Project Title	Urban transportation-related air quality and their impact on human health
Research team	6 members of participants from Indonesia and Taiwan.
Expected outcomes	1. Understanding the determinants of personal exposure to PM and CO in transport microenvironment 2. Understanding and enhancing the knowledge and perspective of citizens on transport-related air pollutants 3. Understand the impact of pollutant exposure to human health in certain environmental/ meteorological conditions 4. An input for stakeholders in designing and implementing policy related to air pollution, especially in transport microenvironment 5. A platform of regular meeting and discussion between researchers, academia, and citizens to seek for effective solution 6. International and local publications on scientific journals/proceedings

Project Title	Interface between science based data and policy action to improve the existing Mandalay City Waste Management : Ambient Air Monitoring, Air Impact Assessment, Personal $PM_{2.5}$ Exposure, Health Risk Assessment, Awareness and Mitigation Measures
Research team	3 members of participants from Myanmar and Taiwan/ 2 consultants from Thailand and Japan
Expected outcomes	1.The project will reveal the existing air quality status (particulates and climate change gases) around the final disposal sites along with the dispersion effect 2.The project will determine the $PM_{2.5}$ exposure level of the waste workers working around the waste disposal sites 3.The data obtained will be processed to identify health risk of the exposed community potentially affected by particulates generated from the waste disposal sites 4.The community perception, awareness as well as policy inputs will be processed depending on the science based data 5.The mitigation measures will be developed in order to be the sustainable sanitary landfill through the long term policy paradigm.

Flagship Project

In order to strengthen knowledge-based actions through regional synergy and participation, IRDR ICoE-Taipei and National Science and Technology Center for Disaster Reduction (NCDR) in Taiwan have proposed a flagship project to IRDR Science Committee (SC) in 2013, which aims at establishing effective dialogues and collaborations between scientists and local authorities to identify information and knowledge gaps at all phases of disaster management, and to introduce science and technology filling the gaps for better knowledge-based actions.

This project has been carried out by both IRDR ICoE-Taipei and NCDR (ICoE-Taipei-NCDR Flagship Project), in collaboration with major municipalities in Taiwan to better enhance digital emergency preparedness by multi-lateral information sharing. With the collaboration between IRDR ICoE - Taipei and NCDR, we have provided one FORIN report of Morakot Typhoon case study in May, 2014.



Visiting Program

To promote integrated research and practices on disaster risk reduction (DRR), to exchange ideas and information among scientists from different disciplines, and to lay a foundation for partnership networking, advanced DRR training, and collaborative research through exchanging scholars between research institutes.

Review mechanism and criteria include:
Review committee is consisted of three members including the Ex Officio and a couple of SAB members. This committee will review the submitted documents and make decisions on whether to support the applicant.

The criteria, expected outcome, and expected contribution of the visiting scientist program to DRR research shall be decided by the review committee in advance.

The application procedure, criteria, expected outcome, and expected contribution will be posted on the website of IRDR ICoE-Taipei. Please find more relevant information at http://www.cfss.sinica.edu.tw/#/articles/25.

Prof. Slobodan P. Simonovic (Professor and Research Chair, Department of Civil and Env. Engineering, Institute for Catastrophic Loss Reduction, The University of Western Ontario) was invited as senior visiting scholar in APR, 2014.

During Prof. Slobodan P. Simonovic's visit in 2015, the center had arranged several training courses and workshops of "System Approach to Management Disasters", "Decision Support Tools for Water and Environment Systems", and "Flood Control and Flood Risk Reduction Capability, Flood Management Practices and Emergency Response Process" at National Taiwan University, National Chiao-Tung University, and NCDR.

International Partnerships

The center has kept close partnerships with UNISDR, ISC ROAP, START, and other international organizations for implementation as "action network" rather than simply research-based collaborations. Meanwhile, ICoE-Taipei has worked closely with governmental agencies and institutes (Academia Sinica, NCDR, CWB, NCREE etc.) and strengthens the capability in engagement as collaboration partners in regional site studies.

ISC Regional Office for Asia and the Pacific (ISC-ROAP)

The Center has supported "The Fifth Workshop on Psychological Intervention after Disasters (PIAD)" on November 14th-17th, 2016, in Manila, Philippine with the collaboration of ISC ROAP, International Union of Psychological Science (IUPsyS), Chinese Psychological Society (CPS), the Jacobs Foundation, the United Nations University International Institute for Global Health (UNU/IIGH), and the Center for Applied Developmental Science (CADS), Friedrich Schiller University, Jena, Germany. And the center will also support the next PIAD workshop.

Joint meeting with ISC ROAP Steering Group on Natural Hazards and Disaster Risk (SGNHDR) on 21th OCT, 2017 at Taipei, Taiwan.

Discuss Potential for future research/ practical implementation collaborations between IRDR ICoE-Taipei and Steering Group.

Global Change System for Analysis, Research & Training (START)

With collaboration with NCDR, the center has supported and involved in the "Pan-Asia Risk Reduction Fellowship Program (PARR)" from 2014.

Participated in 2016 PARR Fellowship Program Inception Meeting on 7 SEP, 2016 at Manila, Philippines

Future Earth

Introduction

Center for Sustainability Science (CSS) in Academia Sinica has organized a series of events for Future Earth, a major international scientific activity and research initiative on global environmental change and sustainability, to promote sustainability science. Currently, CSS is closely collaborating with Future Earth Global Hub, Future Earth in Asia, and Future Earth Knowledge-Action Networks (KANs) in capacity building programs and actively engaging in these international activities. CSS also assists Future Earth, Taipei to promote multidisciplinary, solution-oriented, and stakeholder-engaged sustainability researches.

Future Earth is a major scientific endeavor supported by the International Science Council (ISC) which was recently formed by the merger between the International Council for Science (ICSU) and the International Social Science Council (ISSC). Future Earth is the global research platform providing the knowledge and support to accelerate our transformations to a sustainable world. Bringing together and in partnership with the existing programme on global environmental change, such as DIVERSITAS, the International Geosphere-Biosphere Programme (IGBP), the International Human Dimensions Programme (IHDP) and the World Climate Research Programme (WCRP), Future Earth is an international hub to coordinate new, interdisciplinary approaches to research on three themes: (1) Dynamic Planet, (2) Global Sustainable Development and (3) Transformations towards Sustainability. It is also a platform for international engagement to ensure that knowledge is generated in partnership with society and users of science. It is open to scientists of all disciplines, natural and social, as well as engineering, the humanities, and law. Scientists in Taiwan have long participated in IGBP, IHDP, and DIVERSITAS since 1990+. Representatives from Academia Sinica have participated in Future Earth visioning process since 2011. Even the launch of Future Earth in 2012 was under the leadership of Past President Dr. Yuan T. Lee (ICSU Presidential term 2011-2014). As one of the ICSU's National member, Academia Sinica has been actively taking part in these processes.

The Governing Council of Future Earth is composed of the ISC, the Belmont Forum of funding agencies, the United Nations Educational, Scientific, and Cultural Organization (UNESCO), the United Nations Environment Programme (UNEP), the United Nations University (UNU), Sustainable Development Solutions Network (SDSN), the STS forum and the World Meteorological Organization. In addition to the Governing Council, Future Earth global community is spread over a series of networks and governing and advisory bodies, which include: Future Earth Governing Council, Future Earth Advisory Committee, Global Secretariat, Regions, Nations, Global Research Projects (GRPs), and KANs. Future Earth is now organizing 2018 Summit which will be held in Bonn on August 27-29, 2018 to facilitate collaborations between GRPs and KANs and to speed up the development of sustainability Science.

Collaboration with Future Earth, Taipei

The National Committee of Future Earth, Academia Sinica, Taipei, for Future Earth, International Council for Science (Future Earth, Taipei) was established in October 2015. CSS assists the operation of the Secretariat of Future Earth, Taipei. The regular meetings of Future Earth, Taipei include the annual Committee Meetings of Future Earth, Taipei, and the Standing Committee Meetings twice a year. The planned activities of Future Earth, Taipei are discussed and approved in these meetings. The 2nd Future Earth, Taipei committee members were appointed in the 2017 Committee Meeting held on September 25th, 2017. The committee includes 27 members from various disciplines and stakeholders.

Activities (*updated to the end of 2017*)

International Symposium CSS co-organized

2017 International Symposium on Sustainability Science (ISSS)

The 2017 General Assembly of ICSU and ISSC was held in Taipei, Taiwan on October 23rd-26th, 2017, which provided a platform for high-level academic communications. Taking advantage of this opportunity that many outstanding scientists from various disciplinary and countries came to Taiwan, it would be great to gain experience and suggestions to search for potential solutions of the problems that Taiwan is facing. Taiwan needs to transition to a low-carbon society and a green economy and also need to address the problem of air pollution resulting from fossil fuels that have yet to be phased out. Tackling these challenges and seizing the transformation opportunities are major issues both for Taiwan and the rest of the world. With strong support from President James C. Liao and President Emeritus Yuan Tseh Lee, the Department of International Affairs, Academia Sinica organized the 2017 ISSS with the collaboration of the CSS. The 2017 ISSS was successfully held on October 22nd, 2017, one day before 2017 ICSU General Assembly. The principal theme of the Symposium is "Interlocked challenges and opportunities on energy transformation and air pollution reduction".

President James C. Liao of Academia Sinica gave the opening remarks which addressed that although "Sustainability" has been recognized by society, implementation is still an important challenge for scientists and policymakers. The Taiwan President Ing-wen Tsai also gave welcome remarks and emphasized the responsibility that Taiwan needs to and will take to improve green energy and the government will keep facilitating collaborations between academic and industry. Dr. Arun Majumdar from Stanford University, USA, and Dr. Hiroshi Komiyama from Mitsubishi Research Institute, Inc., Japan, gave their speeches on "Energy Transformation". Dr. Veerabhadran Ramanathan from the University of California at San Diego, USA, and Dr. John D. Spengler from the Harvard T.H. Chan School of Public Health, USA, also shared their experiences and research on "Air Pollution and Health". The other 6 distinguished panelists were also invited in the Panel Discussion Sessions. More than 400 international/ local participants attended this grand symposium. Vice President of Taiwan, Dr. Chien-jen Chen, gave his closing remarks and addressed that more collaborations between the countries over the world are needed to work on the global challenges and to move towards a more sustainable world.

2017 International Symposium on Sustainability Science on October 22th, 2017

Events CSS organized

Discussion Meeting on Collaboration between the CSS and Future Earth

Prof. Shih-Chun Candice Lung invited the Director of Future Earth Japan Global Hub, Dr. Fumiko Kasuga to have a discussion meeting at National Taiwan University on March 15th, 2017. Dr. Chia-Hsing Jeffery Lee also participated in this meeting. The discussion topics include Future Earth development, promoting Future Earth in Taiwan, and possible collaboration opportunities between Future Earth and CSS. The idea of establishing a "Thematic Institute on Co-Benefit Strategy for Sustainable Living" hosted by the CSS was also discussed.

Workshop on Air Sensor, IT Technology, and Health

The meeting was conducted at Academia Sinica on October 20th, 2017. Future Earth has identified health as one of the key challenges and implementation priorities and is in the process of establishing a Knowledge-Action Network on Health. Regional Future Earth meetings in Asia also have identified air pollution as an urgent topic for regional research collaboration. Moreover, Future Earth has proposed "Climate, Health, and Environment" as the theme of Collaborative Research Action to Belmont Forum. Therefore, Prof. Shih-Chun Candice Lung invited Prof. John Spengler from Harvard T.H. Chan School of Public Health and Dr. Ling-Jyh Chen from Institute of Information Science, Academia Sinica, to have cross-disciplinary discussions on the integrated research and application of air sensors to promote collaboration with experts in air quality, health, and IT.

Workshop on Air Sensor, IT Technology, and Health on October 20th, 2017

Workshop on Future Earth Development

The CSS organized a meeting on Future Earth which is held at Regent Hotel, Taipei, on October 23rd, 2017 (during the 2017 ICSU General Assembly). Nine participants from Future Earth, Taipei, Future Earth Japan Global Hub, Future Earth Australia, Future Earth in Asia, Science Committee for Future Earth, and Harvard T.H. Chan School of Public Health were invited and had fruitful discussions about facilitating Future Earth development and the plans of Future Earth, Taipei. The pathways to engaging Taiwan scholars were also discussed.

Workshop on Future Earth on October 23rd, 2017

Events CSS participated

The 1st Taipei KLASICA Symposium - Collective Behavior Change towards Sustainable Futures in Asian and Pacific Island and Isolated Communities

The 1st Taipei KLASICA symposium was organized by the "International Knowledge, Learning, and Societal Change Alliance (KLASICA)" with collaboration of Future Earth and held at National Taiwan University on November 21st-24th, 2016. The Symposium was the first of a series of symposia on case studies of collective behavior change toward sustainable futures in different contexts and cultures. Dr. Chia-Hsing Jeffery Lee participated in this event. Based on nine case studies and discussions, a set of main lessons learned has been collected. KLASICA is engaging in empirical studies on collective behavior change in the field, to test the findings from the Taipei symposium and to refine the understanding of how change can be catalyzed and how long-term adaptive processes can be established.

The 1st Taipei KLASICA Symposium on November 21st-24th, 2016

3rd Meeting of Regional Advisory Committee of Future Earth in Asia

Prof. Shih-Chun Candice Lung, the Director of International Programs of the CSS and Executive Secretary of Future Earth, Taipei, is also one of the members of Regional Advisory Committee (RAC) for Future Earth in Asia. The 3th RAC Meeting was held in Kyoto, Japan on January 17th, 2017. The mission of the RAC is to coordinate and support sustainability research in Asia and the Pacific - fostering knowledge that builds solutions to the challenges facing the region. The strategic plan of Future Earth in Asia was discussed and the planned activities were endorsed in the meeting.

2017 Gro Brundtland Week of Women in Sustainable Development

Dr. Gro Harlem Brundtland was awarded the 2014 Tang Prize in Sustainable Development and provided part of the rewards to organized "Gro Brundtland Week of Women in Sustainable Development" for a total of three years. One-week science activity would be held in Taiwan - including plenary sessions, symposiums, panel discussions, and exhibitions. The 2017 Bro Brundtland Week was held on March 11th-17th, 2017. Prof. Shih-Chun Candice Lung was invited to be one of the Organizing Committee members. Prof. Shih-Chun Candice Lung and Dr. Chia-Hsing Jeffery Lee participated in the Plenary Speech, Symposium and Panel Discussion at National Taiwan Normal University on March 16th, 2017. The invited plenary speaker was Prof. Fumiko Kasuga, who is the director of Future Earth Global Hub, Japan.

17th Conference of the Science Council of Asia (SCA)

The 17th SCA Conference was held between the 14th and the 16th of June 2017, at the Philippine International Convention Center in Manila, the Philippines. SCA has been working to strengthen the cooperation between scientists and facilitate interactions with policymakers in keeping with its role of providing a multi-functional platform of networking for effective partnerships among the countries in Asia. Approximately 455 scientists from around 13 countries/regions who participated in this 17th SCA Conference had intensive discussions on how Science, Technology, and Innovation could be best utilized for inclusive development. Future Earth organized a session and discussed "Air Pollution and Human Health in Asia" in the conference. Future Earth has prioritized "Health" as one of its key challenges and is in the process of establishing a Knowledge-Action Network on this issue. Regional Future Earth meetings in Asia also have identified air pollution as an urgent topic for regional research collaboration. In this session, Prof. Shih-Chun Candice Lung was invited to give a speech on "Asian Culture-related Air Pollution Sources and Health Implications."

The Belmont Forum: 2017 Asia-Pacific Information Day

Belmont Forum is a global science funding partnership that includes 26 scientific ministries and funding agencies around the globe. Belmont Forum is working collaboratively to support research that integrates natural sciences, social sciences, and stakeholder knowledge to understand, mitigate, and adapt to global environmental change. It is one of the Governing Council members of Future Earth. The Belmont Forum Collaborative Research Action (CRA) proposed by Future Earth is the current funding mechanism that supports Future Earth-generated interdisciplinary research projects. The "Belmont Forum: 2017 Asia-Pacific Information Day" was held in Taipei on 27th-28th October 2017 aimed at putting into practice one of the core missions of the Belmont Forum: Identifying and scoping with stakeholders and communities concerned priorities for solutions-oriented environmental change research. The Future Earth Health KAN was introduced and the relevant topic "Climate, Health, and Environment" was discussed on the second day.

17th Conference of the Science Council of Asia on June 14th-16th, 2017

The Belmont Forum: 2017 Asia-Pacific Information Day on October 27th-28th, 2017

Taiwan Civil Society Forum on the Draft of Sustainable Development Goals (SDGs) - Taipei Forum

To develop localized SDGs and indicators in Taiwan which is relevant to the SDGs proposed by United Nations, Taiwan EPA and National Council for Sustainable Development Network, Executive Yuan, organized a series of the Taiwan Civil Society Forums on the Draft of SDGs. Dr. Chia-Hsing Jeffery Lee participated in the Taipei Forum on October 31st, 2017, to have a clearer understanding of government policies and ideas of civil society about the SDGs.

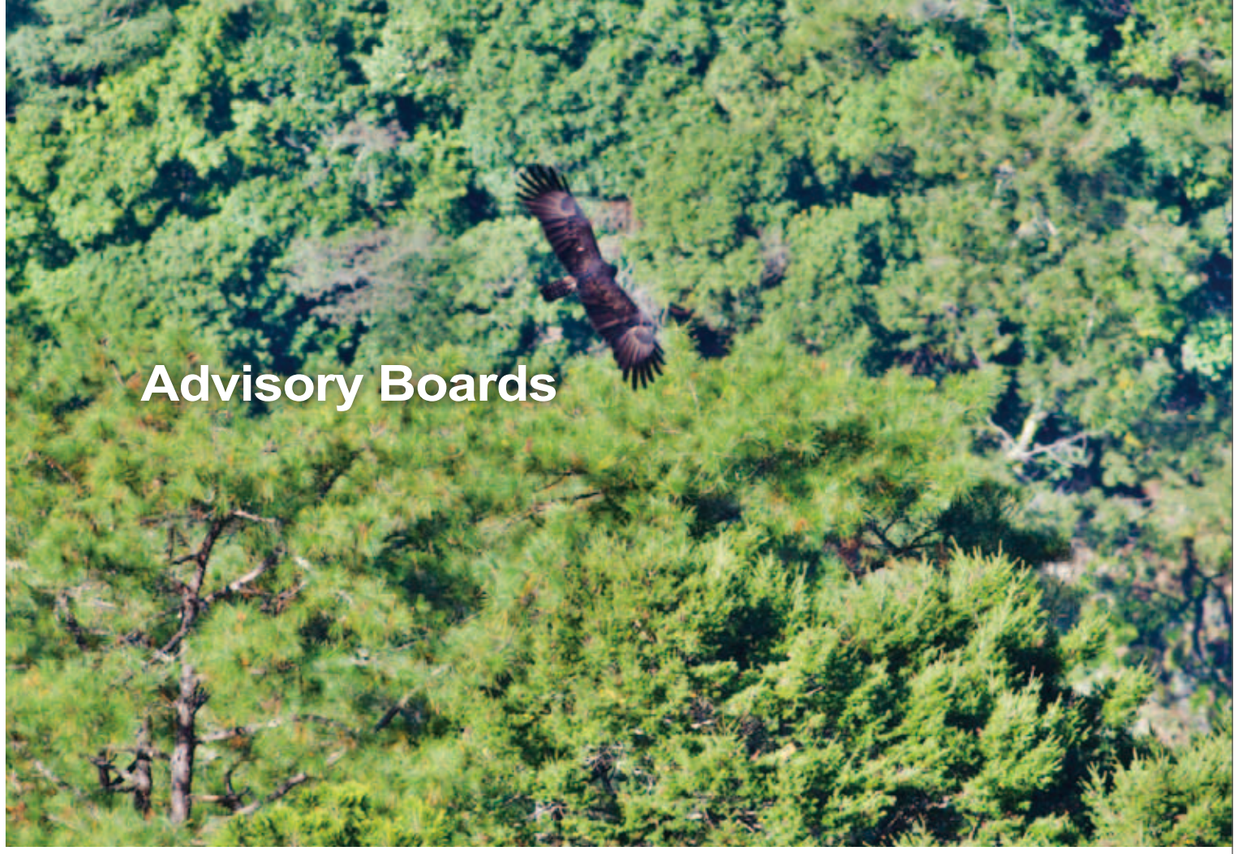
Scoping Workshop of Knowledge-Action Network (KAN) on "Emergent Risks and Extreme Events – Reducing Disaster Risks under Environmental Change"

The newly-developed Future Earth KAN on Emergent Risks and Extreme Events (Risk KAN) is proposed with collaborations between Future Earth, Integrated Research on Disaster Risks (IRDR), and the World Climate Research Programme (WCRP). The Scoping Workshop of the Risk KAN was held in Tokyo on November 22nd, 2017. The main objectives of the workshop were to discuss possible research priorities, practical collaborations and near-term governance of the KAN. Participants also discussed how to engage experts in policy, business and civil society in this collaboration. Science Officer Ms. Si-yu Yu participated in the scoping workshop to better understand the relationship between IRDR and Risk KAN and the progress of Risk KAN establishment.

National Central University Visit

Prof. Shih-Chun Candice Lung and Dr. Chia-Hsing Jeffery Lee were invited to visit the National Central University (NCU) and participated in the discussion meeting on Sustainability Science and Future Earth activities on November 23rd, 2017. The meeting was chaired by Prof. Jou-Tai Wang and Prof. Hwa Chien. The participants also included Academician Chao-Han Liu, Academician Wing-Huen Ip, and another 6 Professors from different departments/institutes. Prof. Lung introduced the Future Earth development and status of Future Earth, Taipei. The Sustainability Science, atmospheric science, air pollution study and highlights of remote-sensing research were discussed by the participants afterward. Prof. Lung and Dr. Lee also had a tour of the Center for Space and Remote Sensing Research and the Environmental Engineering Institute at NCU. The participants also discussed possible ways of collaboration in the wrap-up session, which includes (1) sharing the information of inviting international distinguished scholars, (2) building up the network of international collaborative research networks (i.e. research on Mekon river), and (3) promoting social science and sustainability science in Taiwan International Graduate Program.

Scoping Workshop of Future Earth Risk KAN on November 22nd, 2017



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