GLP Contributing Project Proposal

Land Resources Core Project

Funding source: Department of Natural Sciences and Sustainable Development
Ministry of Science and Technology

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Summary

Land use/cover change (LUCC) is primarily induced by socioeconomic development (anthropogenic forces) and global climatic and environmental change (natural forces). By directly or indirectly impacting regional geophysical processes, LUCC affects atmospheric, climatic, and hydrological conditions. These conditions may cause disaster scenarios which are further aggravated by LUCC. Such destructive events can impede national sustainable management efforts when economies and citizens struggle to cope. Though Taiwan is a country devoted to sustainable management, in the last two decades it has been experiencing tremendous LUCC and increased frequency and severity of floods, droughts, and landslides. “The Land Resources Core Project”, is divided into three categories and seven sub-projects. Implemented over a three year period (Table 1), collaborated scientific efforts in policy, modeling, and the promotion of land sustainability will be integrating on a web-based sustainability platform.

Project Conceptual Framework
# Project Timeline Overview

## Year 1

**Explore** the dynamics and mechanisms of land system changes in Taiwan including cities, villages, slopes, and coastal areas. Analyze the dynamic mechanisms and feedback loops involved in land system changes and various other factors such as the economy, inter-sectoral governance, and atmospheric and climate related impacts. **Integrate** economic and policy considerations into LUCC predictions to identify ways to increase overall land resource robustness.

## Year 2

**Forecast** probable land use change and quantify the uncertainty of predictions. Review CLUE-s literature. Simulate land use suitability as well as LUCC and associated uncertainty based on three scenarios with the CLUE-s GIS model.

## Year 3

**Verify** sub-project interactions to discuss a number of driving forces, with the aim of integrating projects and building a complete GIS model. Estimate future land use changes in the selected research areas with the CLUE-s optimization model.
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I. Introduction

The Land Resources Core Project addresses land resource related issues, with particular emphasis on urgent land systems challenges. It is a collaborative effort of several research teams. The Global Land Project Taipei Nodal Office primarily conducts and orchestrates the research, with participants from different institutions that investigate the status of developed, undeveloped, and developing lands. The main goal is to ameliorate current land system problems and promote appropriate future land use in order to increase sustainable development across the nation in the coming decade.

Beyond providing research progress updates and relevant news, the Land Resources Core Project website informs the public of the importance of suitable land use practices and research outcomes, thereby serving as a comprehensive sustainability platform.

Land Resources Core Project Website

http://lrcp.ntu.edu.tw/
II. The Land Resources Core Project

Project Aim and Objectives

The Future Earth, proposed in 2013, integrates important stakeholders from different fields to foster interdisciplinary scientific research collaboration and to study earth sustainability related issues. Nested within The Future Earth, the Global Land Programme (GLP) advances three main themes for research that include the dynamic changes of land systems, consequences of land system changes, and integrated analysis and modeling for land sustainability. The GLP Taipei Nodal Office is responsible for the research, planning, and execution of the GLP program objectives. The team is locally based, and focuses on Taiwan land systems. The team is expected to contribute research findings to the GLP and to maintain affiliation with The Future Earth.

In support of GLP objectives and to inform decision-making on the interrelationship between the economy, atmospheric and climate related impacts, and inter-sectoral governance, the Land Resources Core Project aims to: understand driving factors, dynamic changes, and change mechanisms of Taiwan land systems. Systems analyses on Taiwan urban, rural, slope and coastal areas will utilize land use change models to investigate development processes, dynamic system change processes, and causal relationships. Economic and policy priority considerations taken while developing land use forecasting models will reflect Taiwan’s land resource resiliency for further discussion.

Research findings will also inform as-needed revisions of the 2016 Spatial Planning Act, which provides assessment data and planning guidance for Taiwan development strategies. By participating in the GLP, the Land Resources Core Project promotes Taiwan as a global model for land use change and sustainability management.
**Sub-Projects**

The Land Resources Core Project is comprised of seven sub-projects with the main project responsible for sub-project research integration. Sub-projects and principal investigators are listed below:

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<td>Associate Prof. Li-Chi Chiang</td>
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As the lead sub-project, Sub-Project 1 will use an updated version of the Conversion of Land Use and its Effects (CLUE-s) modeling framework to estimate the current status and distribution of land use types in Taiwan. Sub-Project 1 is responsible for carrying
out detailed analysis on the dynamic changes and mechanisms of land systems, followed by multi-scenario quantification and simulation. Sub-Projects 2, 3, 4, 5, and 6 will conduct studies on the driving factors of land use change, the causality between the economy and land use, and interactions between the atmosphere and land use. The research results of these subgroups will support the investigations of the lead sub-project while the model developed by Sub-Project 1 will contribute to Sub-Projects 2, 3, 4, 5, and 6 conclusions. Predictive simulation results will be integrated into Sub-Project 7 for qualitative environmental management and risk analysis. Consolidated end results will be both quantitative and qualitative for resilient land use management strategy planning and future development assessments. Sub-project abstracts are presented in the next section.
Sub-Project 1: Modeling Dynamic Changes and Mechanisms of Land Systems

Prof. Yu-Pin Lin, Prof. Shih-Liang Chan, Associate Prof. Shiau-Yun Lu, and Associate Prof. Li-Chi Chiang

Land use change is a spatiotemporal process that includes a large number of interrelated natural and anthropological factors. Due to the uncertainty originating from these factors and the complex interactions between factors, predicting future land use change is problematic. Land use change models, however, can identify the causes and effects of land use change. Land use planning and policy, then, is further supported when informed by land system functional element quantification, land use type and driving factor interaction analyses, and land use change prediction. Accordingly, this sub-project will establish a GIS-based module to: identify the relationship between existing land use types, analyze land use changes and driving factors, predict future land use change, and resolve uncertainty issues from data, model parameters, and modeling procedures. The objectives of this three-year sub-project are as follows:

Year One: Generate Taiwan land use suitability maps by identifying linear and nonlinear relationships between land use change and predictors of change. Utilize GIS-based land-use suitability module of five models, 1) Generalized Linear Model, 2) Generalized Additive Model, 3) Artificial Neural Network, 4) Support Vector Machine, and 5) Random Forest. Calculate AUC value and variations of each suitability map generated from different land use categories and methods. Validate identified driving factors and further discussion.

Year Two: Simulate Taiwan land use change using Conversion of Land Use and its Effects (CLUE-s) model with different land use scenarios including, maximum AUC value suitability map combinations, high AUC value suitability map combinations, and greater than 0.6 AUC value suitability map combinations per land use category. Develop GIS-based model for Bayesian uncertainty quantification.

Year Three: Identify and analyze land use change driving factors for selected land use types within the study area, and for each sub-project. Integrate total sub-project model data into a user-friendly GIS module.

The global impacts of coastal disasters demonstrate the high vulnerability of coastal
cities and the urgent demand for establishing coastal city resilience. The Taiwan island’s critical need for a comprehensive coastal plan, is evidenced by the 2014 Coastal Zone Management Act. Accordingly, coastal LUCC will also be examined in detail during Sub-Project 1 execution. Specifically, modeling resilient coastal cities will identify indicators for coastal city vulnerability calculations, and for coastal land use planning strategies and policy development.

Sub-Project 1 is the leading edge for Taiwan participation in global land use research. Because it is the first nationally funded research project of its kind that considers the relationship between land use change and driving factors, as well as uncertainty analysis based on an optimal CLUE-s model, this project will enhance the international influence of global land use research and nurture local talent. Additionally, the GIS-based module will be used to simulate different national land use planning scenarios to inform decision-makers.
Sub-Project 1 Flow Chart
Taiwan was once known as “Formosa” due to its plentiful forest resources. The mountainous landscape, high species diversity, location within the East Asian Monsoon region, along with its high annual average rainfall of 2500mm per year, have formed Taiwan’s unique ecosystem. Under rapid population growth, limited land resources, and to satisfy demands, however, many slopes have been transformed by continuous development into farmland or residential areas. Because land use and/or land cover changes can lead to environmental issues such as flooding, water pollution, and landslides, the objectives of this three-year sub-project are as follows:

Year One: Analyze changes in land and water resources and examine the influential factors of major disasters in watersheds.

Year Two: Establish a management model based on LUCC hot spot areas from multi-scale perspectives, e.g., large scale (river basin), medium scale (management unit) and small scale (cadaster and pixel levels).

Year Three: Draft a strategic plan for response to environmental change using three case studies that evaluate the potential deep-seated landslide areas in a watershed. Identify the optimum groundwater recharge site to counteract significant watershed subsidence, and discuss the spatial distribution change of carbon sequestration in a watershed. Maintain an integrated stewardship model in the watershed for conservation and monitoring management that informs authorities.

Sub-Project 2 will analyze the multi-faceted aspects of environmental issues in a watershed including, landslides, floods, wildfires, water resource conservation, grassland succession, and wetland conservation by using environmental indices. Research results will enable further exploration of LUCC driving factors and impacts.
Sub-Project 3: Urban Land Use Change and Resilient City Land Management in Taiwan

Prof. Hsiao-Lan Liu

Urbanization is one of the critical factors that impact global environmental change in the 21st century. High-density development, land use patterns, urban structures, and consumption patterns in urban areas contribute to CO2 emissions and increasing temperatures. In recent years, people have become aware of the severe risks that climate change pose for our cities, particularly the threats to urban infrastructures, ecological systems, and urban economic development. Thus, the concept of resilient cities has gained considerable attention and interest in past few years and land use management in and around cities should be considered when establishing a resilient city plan. The objectives of this three-year sub-project are as follows:

Year One: Investigate Taiwan’s urban LUCC as well as its driving forces from 1995 to 2007.

Year Two: Apply tele-connection concepts to examine the factors that influence urban land use change in Taiwan, and how urban LUCC impacts climate change.

Year Three: Develop a resilient city land-use management strategy based on research findings.

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1 LU, P. & STEAD, D. 2013. Understanding the notion of resilience in spatial planning: a case study of Rotterdam, the Netherlands, Cities (SSCI)
Sub-Project 4: Rural Land Use Change and Make Resilience Rural Land Use Management in Taiwan

Prof. Chen-Fa Wu, Prof. Feng-Tyan Lin

Rural countryside functions are essential for understanding social and land system interactions, and are the top agenda of many international research projects. The 2015 National Land Use Planning Act provides instructions for agricultural development planning along with relevant principles applicable to rural areas. An impact assessment of current and successive policies, however, for an overall land use strategy assessment will inform future policy decisions. Accordingly, this study will investigate the national land use changes in Taiwan from 1995 to 2007, and construct a resilient land use management model. In order to increase national support of rural countryside functions and to synchronize our results with other international research projects and trends, Sub-Project 4 focuses on three rural countryside functions including crop production, countryside amenities, and ecosystem services. The objectives of this three-year sub-project are as follows:

Year One: Investigate and discuss the national land use change processes in Taiwan and their underlying driving forces by utilizing both a comprehensive literature review and the project ground theory. Analyze the effect of multiple factors on land use distribution, change, and change processes with binomial logistic regression. Quantitatively evaluate land system dynamic change mechanisms for simulations.

Year Two: Analyze public perception of national land use and environmental change in Taiwan. Construct a public perception questionnaire framework based on literature review and conduct field interviews during the field questionnaire survey. Examine the relationship between land change perception, disaster experiences, coping behaviors, coping strategies, and strategic opportunities with Path Analysis to identify the differences in public perception among high, medium, and low land use change areas. Propose national land use change management strategies based on public feedback and opinions.

Year Three: Select agricultural development areas as research sites as per the National Land Use Planning Act intent. Simulate land use change under distinct agricultural development resilience strategies executed with specific agricultural development area plans. Investigate and compare the appropriateness of agricultural development areas
and strategies under different scenarios. Source scenario input data from complimentary sub-project land use change simulation results. Compare land use distributions and ecosystem services yielded under different circumstances. Assess the National Land Use Planning Act effects on farmland recovery areas, agricultural development area locations, and ecosystem service recovery using the reference year 1970. Discuss proposed national land use management resilience models.

Sub-Project 4 will propose a land use management resilience model to evaluate the effects of current land use practices and the National Land Use Planning Act. Research experiences of the Taiwanese situation will be shared with the international community via the Global Land Programme.
Sub-Project 5: Assessment of Land Use Strategies for Economic and Environmental Sustainable Development: Applications Linking Global and Taiwan Computable General Equilibrium Models

Associate Prof. Huey-Lin Lee

Land resources play myriad roles in human economic activities—they are key inputs for the production of diverse goods and services and offer free ecosystem services to support social amenities. Economic development shapes the pattern of land use change while sustainable development of the economy and society requires well managed and functioning land resources and ecosystem services. Following the International Council for Science (ICSU) call for academic research on the construction of Integrated Spatial Decision Support Systems, Sub-Project 5 will integrate economic activities and land use change in order to conduct a systemic assessment for national land use policy.

Taiwan has become both biophysically and economically susceptible to global changes due to a high dependency on exports while increasing economic globalization and urbanization intensifies competition for land resources. Given the existing land endowment system, strategic management practices take the economic efficiency and practicality into account while reallocating land resources. Since land management policy guides the economy towards efficient allocation land uses, and high specialization in economic production implies that manufacturing sectors are inter-dependent on one another, inter-industry and inter-sectoral dependencies must be recognized when resource allocation decisions are being made. To address this, Sub-Project 5 will develop a computable soft-linked global general equilibrium-modeling module for Taiwan to describe the interconnection between domestic and international consumer groups, the manufacturing sector, and resultant land use competition.

Land management policy is crucial in guiding the economy towards efficient allocation of various land uses. The high specialization in economic production implies that manufacturing sectors are inter-dependent on one another. Therefore, it is important to recognize the inter-industry dependencies between sectors when resource allocation decisions are being made. The developed module, Integrated Spatial Decision Support System for Taiwan (ISDSS-TW), will serve as a land use policy assessment tool for both public and private sectors. The ISDSS-TW will inform coping strategies to simulated economic growth and land use change consequences under various scenarios,
including those that reflect global and national changes in the biophysical, social, and the economic environment. The objectives of this three-year sub-project are as follows:

Year One: Develop an environmentally extended Input-Output Account with incorporated Input-Output Tables and Taiwan Land Inventory Data. Identify the interdependences between manufacturing sectors that contribute to the Taiwanese economy and associated sectorial demands for land resources. Identify land use hotspots, the “key sectors” in driving economic growth, and contributors to the derivation of land multiplier effects for all sectors.

Year Two-Three: Identify sectors that are suitable for cooperation based on indicators from the developed approach. Analyze various scenarios such as world trade regime changes, global environmental changes, and domestic social and economic development in response to exogenous and internal perturbations with the module including economy-wide assessment model, particularly the computable general equilibrium model. Offer insights for land management policy in the contemporary economy of specialization.
Sub-Project 6: Interactions between Taiwan’s Land Use/Cover Change, Regional Atmospheric and Hydro-Meteorological Modeling, and Large-Scale Climate Variability

Assistant Prof. Chia-Jeng Chen, Associate Prof. Jehn-Yih Juang
Assist Prof. Min-Hui Lo

Land use/cover changes (LUCC) can affect the atmospheric, climatic, and hydrological systems at both global and regional scales and can aggravate natural hazard events such as flooding. Although Taiwan is committed to sustainable management, the country has recently undergone rapid LUCC while the number of intense hydro-meteorological disaster events per decade is increasing. In this context, Sub-Project 6 will disclose the implicit interactions between LUCC in Taiwan and regional atmospheric and hydro-meteorological conditions. By employing broad-spectrum analyses such as analytical, empirical/statistical, and dynamical modeling, large-scale climate variability will also be addressed. Separately developed research directions at distinct spatial and temporal scales will synergistically answer the following questions:

1. Has LUCC altered local/regional weather systems (e.g., convective systems in metropolitan areas)?
2. What is the underlying mechanism of LUCC that influences atmospheric conditions and land-surface fluxes (and/or vice versa)?
3. Can any large-scale circulation patterns that correlate with LUCC-related variables (e.g., temperature, precipitation, sensible and latent heat, and vegetation index), potentially driving the long-term LUCC, be identified?
4. If it is possible to further hypothesize the influence of climate variability on LUCC, is it possible to depict the trend and variation of those transient atmospheric processes in the long run?
5. Is there any secondary or tertiary impact from LUCC to other environmental systems (e.g., watershed- and metro-scale hydrology)?

Future interactions between LUCC and atmospheric dynamics under climatic change will also be quantified in order to leverage discussion and findings regarding the above questions. The objectives of this three-year sub-project are as follows:

Year One: Analytically and statistically analyze the relationship between LUCC and the dynamics of thermal environment at target weather stations in Taiwan from 1950 to
2010. Empirically analyze (e.g., EOF, SVD, and composites) the correlation between climate indices (i.e., teleconnections) and the LUCC-related variables at the target stations and extended watersheds.

Year Two: Empirically analyze complimentary sub-project dynamic LUCC statistics provided and discuss correlations between the LUCC-related variables and LUCC statistics. Prepare offline, uncoupled simulations (with prescribed forces) on WRF, Noah, WRF-Hydro, and SWMM to understand first-order impacts of LUCC on changes in surface temperature, precipitation, fluxes, and hydrological responses.

Year Three: Run coupled WRF-Noah, WRF-Hydro, and WRF-SWMM simulations to explore the relationships and underlying mechanisms between LUCC, atmospheric convection, and hydrological responses. Integrate findings into prediction model of future LUCC and atmospheric dynamics.
Sub-Project 7: Theorization of De-Territorialized Environmental Risk Assemblage under the Context of East Asian Industrial Land Process- a Scalar Perspective of “Built Environment in the Urban” and “Earth Force in the Region”

Prof. Shiuh-Shen Chien

Territorialized and de-territorialized environmental risks (ERs) are important research topics in many industrializing and industrialized countries. Existing literature, however, mainly focuses on territorialized ERs which are geographically near to current risks in study areas versus de-territorialized ERs which are geographically distant to current risks via transportation mechanisms. De-territorialized ERs cannot be understood merely through the analysis of risk materials themselves. Instead, de-territorialized ERs are better understood as ER assemblages consisting of risk materials, risk transport mediators, and fragmented governance of these risk materials and mediators. Sub-Project 7 gives insights into the lesser studied de-territorialized ERs.

Categorized into at least two types of mediators, de-territorialized ERs are either: (1) man-made transportation mechanisms such as infrastructure, and (2) natural transportation mechanism such as wind. De-territorialized ERs are discussed in terms of three analytical dimensions including spatiotemporal which refer to ER air column altitudes, subterranean depths, seasonal variations, as well as the rapid dynamics involved during explosions; ER transportation and formation mediators such as the differences and commonalities of transformation and formation processes; and social-spatial processes such as both built-up structures in the urban environment and the strength of geophysical processes in regional contexts.

A theoretical framework of ER assemblages provides an opportunity to explore the different political and social environmental scenarios, the intermediaries of ER transmission, and the various institutional advantages and limitations of ER management. Sub-Project 7 examines a theoretical framework of ER assemblages by referring to two cases from Taiwan and China that have undertaken similar de-territorialized ER management in recent years. While Taiwan possessed a more government more accountable for its actions, China’s strong central authority can coordinate large-scale administrative measures with or without popular consensus.
The Integrated Structure and Work Allocation

This integrated interdisciplinary project addresses a variety of topics, including: policy, economics, urban studies, and rural studies as well as the dynamics of slopes, coastal areas, atmospheric conditions, and land use patterns. Sub-project 6 is responsible for environmental data collection and database building. The responsibilities of main project include building the land use database and rendering the figures, which include satellite imagery and both digitized and non-digitized data. Sub-project 5 is responsible for the socioeconomic database. Sub-project 7 is responsible for organizing the policy database, which includes both domestic and international relevant policies. The main project and sub-project 1 supports the development of research tools like GIS, satellite imagery software, statistical software and the land-use change model. The primary responsibilities of each sub-project and the main project are depicted as an integrated and collaborative project structure shown below.
III. Research Schedule

Expectations for completed work are as follows:

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<th>Year 1</th>
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<tr>
<td>• Complete literature review on dynamic changes of land use</td>
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<td>• Collate Taiwan land use data by year</td>
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<td>• Model overall and explicit land use change dynamics via GIS-based models</td>
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<td>• Conduct interactive verification of each sub-project’s land use change driving factors</td>
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<th>Year 2 (Current Stage)</th>
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<tr>
<td>• Complete literature review on the Conservation of Land Use its Effects at Small region extent (CLUE-s)</td>
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<td>• Verify land use and driving factors analysis model</td>
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<td>• Analyze uncertainties of land use and driving factor analysis model</td>
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<td>• Select land use combination scenarios with three methods (use AUC&gt;0.6 as threshold, apply Simulated Annealing to select land use types, and use the combination of highest AUC values as objective function)</td>
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<td>• Use CLUE-s to analyze land use types selected by three methods and establish suitability maps to forecast future land use scenarios</td>
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<td>• Model land use uncertainty and verify the future land use simulation results</td>
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<td>• Optimize the GIS-based CLUE-s model</td>
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<td>• Build the GIS-based land use uncertainty quantification model</td>
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<th>Year 3</th>
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<tr>
<td>• Select specific study regions, analyze dynamic changes and driving factors</td>
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<tr>
<td>• Conduct interactive verification of driving factors identified by each sub-project</td>
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<tr>
<td>• Conduct CLUE-s analysis with the above mentioned three methods to simulate future land use scenarios</td>
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<td>• Verify the forecasted land use scenarios</td>
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<td>• Build the holistic GIS-module</td>
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<td>• Recommend a resilient land use strategy for Taiwan</td>
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Conclusion

The Land Resources Core Project has completed a literature review and ground theory study, established a database, and completed an investigation into the GIS-based land use change model dynamics in its first year. Driving factors and various scenarios will be examined in detail with the application of different models following the project timeline.

Outcomes will significantly contribute to several areas, including: academia, policy deliberation, and the international promotion of land use research. Sub-project teams will communicate and share results at scheduled meetings, workshops, and seminars for maximum research integration, consensus, and impact. Domestic and international feedback on shared findings and modules will aid in formulating amendments suitable for practical approaches.

Taiwan’s research contribution will demonstratively promote practical and sustainable development within The Future Earth paradigm. The Global Land Programme Taipei Nodal Office will present its findings to the GLP committee and international GLP fellows at GLP international conferences and workshops. Shared experiences will aid in identifying potential or emerging trends within the international community.