Evaluation Tools to Identify Implications of Climate Change and Economic Development for Sustainability in Lijiang and Yulong Mountain Region, China

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Abstract
Research on developing well designed evaluation tools will provide the information and understanding necessary for identifying more effective adaptation options and better management plans for ensuring regional sustainability. This paper presents an integrated approach that integrates ecosystem vulnerability identification, adaptation option evaluation, and multi-stakeholder participation. The integrated approach will be applied in Lijiang and Yulong Mountain region of China for identifying desirable resource management plans to reduce ecosystem vulnerabilities. Different computer- and non-model based methods will be adopted to form the integrated approach. The research starts with data collection and the identification of vulnerabilities of ecosystems and economic sectors to climate and socio-economic changes. This is followed by survey and interviews that allow stakeholders to participate in a multi-criteria evaluation of adaptation options. The analytic hierarchy process (AHP), an MCDM technique, will be employed as an adaptation evaluation tool to rank desirability of resource management plans. The paper will provide some articulation on how the integrated approach can provide an effective mean for the synthetic evaluation of the general desirability levels of a set of resource management plans through a multi-criteria and multi-stakeholder decision making process. Thus, the study contributes to the science of ecosystem assessment.

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1 Introduction and Background

Facing the environmental challenges of the 21st century, a better understanding of the consequences of global environmental change and economic development in mountain regions will be essential. Integrative research approaches are required to translate scientific information into public awareness and effective policy response. Signed by more than 800 scientists at the joint IGBP/IHDP/WCRP Global Change Open Science Conference "Challenges of a Changing Earth" in July 2001, the Amsterdam Declaration states that the accelerating human transformation of the Earth's environment is not sustainable, and that a new system of global environmental science is required that will integrate across disciplines, environmental and development issues and the natural and social sciences. This is particularly true for mountain

regions, given the sensitive, dynamic and complex nature of the relationship between mountain environments and the increasing number of people who inhabit and are visiting them.

In Lijiang-Yulong mountainous region, an extremely important water and mountain ecological region, has to provide a number of competing users with a range of different and often conflicting functions to meet their demands. While the demands for water and ecological resources increase dramatically as population and economic grow, the availability and the inherent functions of ecological systems are being reduced by climate change, water pollution, rapid tourism expansion, and environmental degradation. Unsustainable resource uses have created a sharp decline in natural resource availability and increase in resource use conflicts.

Under climate change conditions, reduced rainfall and water supply associated with glaciers retreats might increase water use conflicts and threaten the tourism industry and economy of the region. Yulong Mountain is the south most snow-capped mountain in China. Scientists project a disappearance of between one- third and one-half of existing mountain glacier mass by 2100. Yulong mountain glacier has already been observed to be in rapid retreat. From 1982 to 2001, Yulong White Water number 1 glacier retreated about 150 meter, which is threaten. In Lijiang, the water supply for more than 1.1 million people depends on the spring melt from the glacier that is now in rapid retreat, for reasons that may or be related to increasing economic activities and global climate change. Water supply declining will affect both tourism industry and agriculture with thirty percent of the irrigated farmland. Climate change may also cause negative impacts on other economic sectors in the region.

Since the 1996 earthquake, economic investment in Lijiang has increased significantly. Many new buildings, tourist facilities, new roads and other infrastructure in Lijiang City have been developed. With rich tourist resources in ethnic minority culture, biodiversity, and natural scenic spots, tourism growth with an annual income of more than 100 million RMB is achieved. Many modern hotels have built and family hostels are popular in the old city district. The tourism sector in Lijiang relies on water which supports scenery streams and generates hydropower.

While the development of tourism sector in the region has brought considerable benefits to people living in the poor region, new problems have begun to emerge. For example, the ecological damage associated with tourism development is becoming a major concern in China. The primary product of tourism industry is often the heritage, natural wealth, and expected legacy of the local community that serves as the tourist destination. Tourists can outnumber the resident population in tourism seasons. When the passengers exceed the carrying capacity thresholds of the ecosystem, ecosystem degradation will occur. Thus, poorly planned or designed development will harm the wilderness area.

It is recognized that tourism is often a major source of environmental and, in some cases, cultural pollution. Tourism development may place certain elements of the local culture in peril with large number of visitors. If tourism activities degrade the community's heritage and natural wealth, then local communities will suffer more directly than the tourists. The intrusion of large numbers of tourists into local social systems can undermine pre-existing social relationships and values. This is particularly a problem where tourism activities are centered in traditional social systems, such as minority communities. The rapid tourism development in Yunnan Province has

been bringing some social problems such as a burgeoning sex trade that spreads sexually transmitted diseases including HIV.

In this respect, the International Institute for China Development at University of Hong Kong , Yunnan Institute of Finance and Economics, the CAREERI/CAS, will work with Adaptation and Impacts Research Group (AIRG) of Environment Canada, Sustainable Development Research Institute (SDRI) of University of British Columbia (UBC) to carry out a project in Lijiang-Yulong Mountain region.

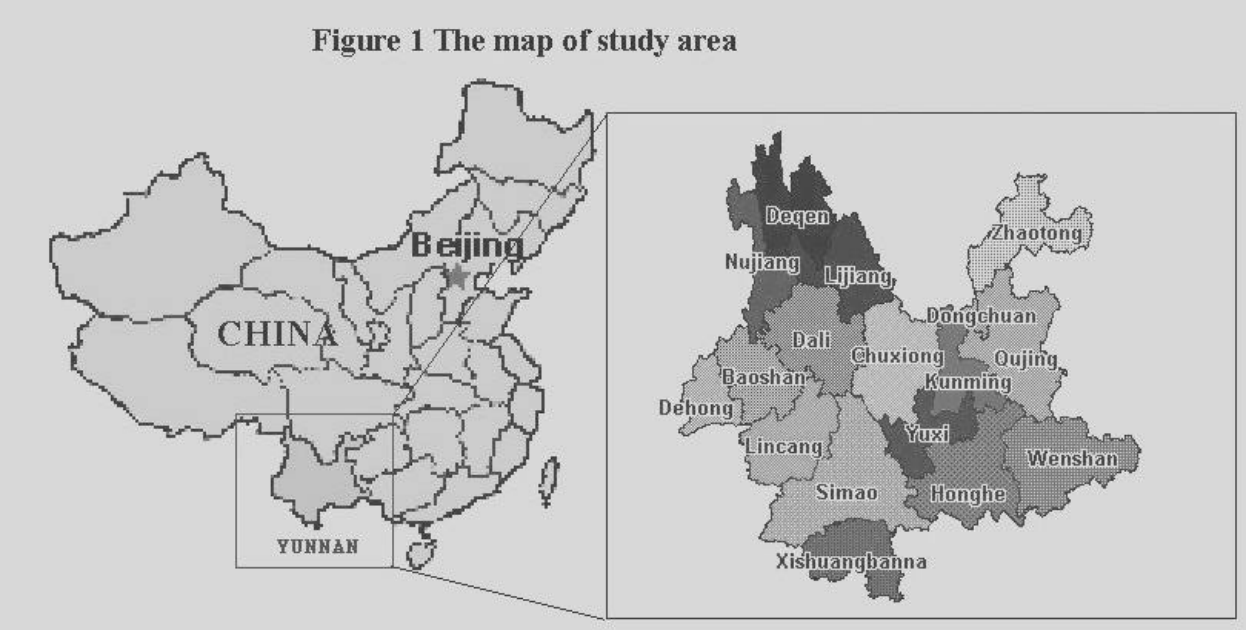
2 Study Objectives and Expected Outputs

The purpose of the project is to develop an integrated approach (IA) for identifying socio-economic and ecological impacts of economic growth and environmental change on regional sustainability, and for evaluating policies or options to deal with these impacts. The IA will provide a research framework which integrates socio-economic development scenarios, climate change scenarios, vulnerability assessment, sustainability indicator specification, and policy evaluation. The proposed IA will provide an effective means for synthetic assessment of socio-economic and ecological impacts associated with regional development and climate change, and evaluation of the general performance levels of a set of policies and planning options through a multi-criteria and multi-stakeholder decision making process. Thus, the research will contribute to science on regional assessment and policy evaluation. In particular, the proposed project is to address two fundamental questions: How will rapid economic growth, tourism development, and global environmental change affect ecosystem sustainability and human well-being in local communities? And how can we enhance human well-being while reducing adverse effects of tourism and economic activities, as well as global change on regional sustainability? The study will have the following outcomes.

1. Detect signals of global environmental change in mountain ecosystems and predicting future regional economic growth and tourism development;
2. Assess the socio-economic and ecological consequences of global environmental change and economic growth for mountain regions as well as lowland systems dependent on mountain resources in the study region; and
3. Evaluate policies or regional development plans towards sustainable tourism development, water and resource management for mountain ecosystems in the region.

3 The Study Area

The project's geographic focus is Lijiang-Yulong Xueshan region in Yunnan Province (see Figure 1). It is part of the western region in China with fragile mountain ecological systems. Lijiang Prefecture, located around 27°N (latitude) and 100°E (longitude), depend on the glacier as a natural reservoir for its water supply. The IA will be applied to the study area to examine the implications of climate change and economic development for regional sustainability. Early 2000, the Chinese central government launched a major, new initiative to develop China's poor, backward western regions. China’s National West Development Strategy has opened a new chapter of economic growth and expansion in China’s western regions.



The motivations behind the West Development Strategy are aimed at rapid changes in Western China over the next few decades and easing the income disparities between coastal and interior China. Chinese government plans to invest resources in the development of transportation and communications infrastructure, education, ecosystem protection and natural resource management. The Yuanan provincial government started to implement a strategic plan in 1990s to develop the scenic resort of the Yulong Snow Mountain and to build Lijiang into an important tourism area of Yunnan Province. Western China's ecosystems and economy will be affected by the new development. With the most fragile ecosystems in the nation, Western China is quite vulnerable to rapid economic growth and potential climate change.

Enhancing the region's capacity to manage its ecosystems would promote sustainable development in the region. Capacity building of the project will include providing training to enable local scientists to undertake the impact assessment and policy evaluation (e.g., data collection, modeling, impacts assessment, policy analysis tool designing) themselves. Those local scientists will be in a position to continue research and participate in future assessments in the region. With improved knowledge and skill of the ecological conditions and adaptation options, the region can make more sustainable decisions in the future.

4 An Integrated Assessment Approach

The proposed project will design an integrated approach for identifying resource system vulnerabilities to climate and socio-economic changes, and for evaluating adaptation options to deal with vulnerabilities. In particular, the proposed project addresses the following gaps in ecosystem vulnerability and adaptation science:

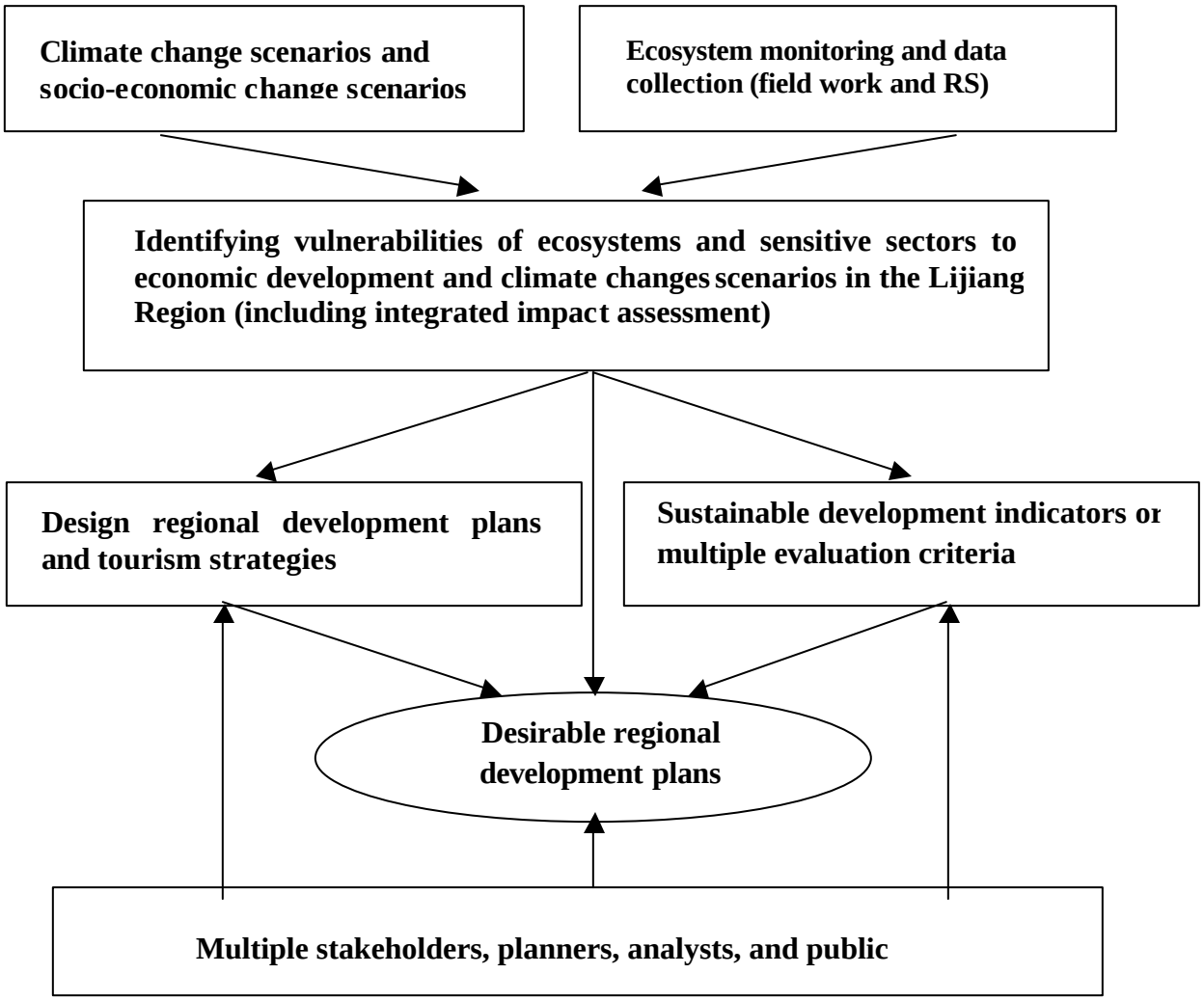
- The research will measure existing ecosystem vulnerabilities including the adaptive capacity of current institutional and physical structures to deal with climate variations and other socio-

economic changes. Critical thresholds of vulnerabilities and barriers to adaptation in the resource systems will also be examined;

- An integrated assessment (IA) framework will be developed to enhance adaptive capacity of resource planning and management to the impacts of climate change and other socio-economic changes; and
- The research framework will integrate sensitivity analysis, vulnerability indicator setting, vulnerability assessment, and adaptation option evaluation.

Figure 2 shows the general approach of the study. The following describes briefly the main components of the research approach (Please see Figure 2).

Figure 2 Flow-chart showing the research structure of the IA approach



Ecosystem Monitoring and Data Collection

Data required for this study include ecosystem stability, areas of different types of land, erosion, water supply and demand, average yields, prices of products, costs of production, population growth rate, tourist information and other regional data. The data collected also have spatial and temporal dimensions. The model variables and parameters differ among sub-regions, and vary between the present and the future (changed economic and ecological condition). Thus, the database consists of information for each land unit under both current and future conditions.

Data required for the identification of vulnerabilities to climate and economic changes will come mainly from several sources: field work, survey, expert judgement, existing data derived from previous studies on various research, government documents, statistics and reports, and scientific literature.

Monitoring and analyzing of indicators of environmental change in the region will be one major research activity for the proposed project. This research component will focus on ecological indicators of environmental and economic changes. This indicator system includes sub-groups such as cryospheric indicators related to snow conditions, glaciers, and permafrost. Historical and current data on terrestrial ecosystems, freshwater ecosystems (streams and lakes) will be collected and analyzed. The research will also study the watershed hydrology and water balance in the region. Some monitoring activities and field work will be conducted on the following aspects:

- Material balance of the Yulong glacier;
- Glacier climate and hydrology; Glacier change and retreat;
- Regional geological structure; and
- Regional geological thermal resources.
  Fundamental to this analysis is the use of land cover and land use change (LCLUC)

Information derived from remotely sensed data will also be envisioned. Remote sensing image processing technology will be used for collecting and updating land cover and land use information. Application of remote sensing image processing in ecological and economic impact assessment can facilitate the process of data collection and the measurement of land use changes. Timely updated information about the regional resource base is essential for analysis. Specific computer software technologies for satellite image processing will be employed to extract, enhance, and classify digital image (Gong et al., 1999; Qi et al., 2000; Gong, 2000).

Socio-Economic and Climate Change Scenarios

In identifying present-day environmental risks, and conducting ecological and economic impact assessment and adaptation option evaluation, existing economic growth and tourism development trends, climate variation patterns, and future climate change scenarios need to be specified to examine regional economic, social, and environmental impacts. The project will begin with a careful study of the present-day ecological and economic impacts of economic and tourism development. This will provide a baseline set of measurements that can be used to assess societal vulnerabilities to future climate and socio-economic changes.

In the project, three types of scenarios will be specified: climate change, future socio-economic conditions, and adaptation options. In developing climate scenarios, the study will identify a set

of scenarios representing current climate variation and future change. The vulnerability assessment needs information on specific frequency and/or magnitude of climate events.

An analysis of how land use has been changing for the past 30 years over selected areas in the study region with respect to policy, population and economic increase and ecosystem condition change with some reasonable projections into the future would provide insights to the impact assessment to socio-economic and climate changes. To handle a variety of data sources containing both spatial and non-spatial data, a geographic information system will be used to serve as a spatially-referenced database for integrated analysis. The GIS system will be used for data manipulation and results display.

Various methods will be used to project future tourism development, population increase and economic growth. Those economic sectors (tourism, water resources, and agriculture), and fragile ecological systems sensitive to climate and economic changes in the region will be included for integrated assessment.

Changes in socio-economic conditions, such as population, income, technology, consumption rates, and new region development strategies or plans, will be taken into consideration in setting future socio-economic scenarios. Various methods will be used to set future population increase and economic growth scenarios. Lijiang government development strategies and plans will be evaluated to select more desirable development plans for the region. To improve quality of evaluation, workshops and community consultations with multi-stakeholders in the region will be held to identify regional concerns related to socio-economic goals.

Vulnerability Assessment

Tools of both computer-based and non-model based methods will be used for measuring vulnerabilities to determine how vulnerable these sensitive systems are to climate variations and socio-economic changes. Survey, empirical observations, and expert judgement methods will be used to study the impacts and stresses of present-day conditions, and to evaluate existing adaptive capacities of various key sectors sensitive to climate variations and socio-economic changes. Ecological and economic impacts of current economic growth and climate variation will provide a baseline set of measurements and observations that can be used to measure progress toward reducing vulnerability to future economic and climate changes. Once these vulnerability measures are identified for each economic, ecological, and social vulnerability indicator, they can be applied to project potential vulnerabilities of the sensitive sectors to future climate and socio-economic change scenarios. Thus, the research on present vulnerabilities and adaptive capacities of human and ecological systems will provide insights into potential impacts and vulnerabilities associated with future climate and socio-economic changes.

Additional analyses of the social, economic, and ecological impacts (negative and positive) of alternative economic and climate change scenarios for different economic sectors will be undertaken to fill impact data gaps for key sectors that are sensitive to climate and socio-economic changes. To improve impact information, expert judgement, and various ecological simulation or statistical models, GIS, will be employed to identify impacts of climate and socio-economic change scenarios (Yin et al., 2003; Yin et al., 2000; Yin et al., 1999; Kang et al., 1999; and Cheng, 1997). These models will be modified based on regional conditions and will be

tested before application for this project.

While the study attempts to identify the vulnerabilities of ecosystems, tourism sector, water resources, agriculture, and regional minority communities to climate and economic changes, it will also develop an integrated assessment system to link different sectors to conduct multi-stakeholder and multi-criteria analysis.

Identify Desirable Adaptation Policies to Improve Regional Sustainability

There is an evident need for new research approaches and tools that are able to evaluate alternative adaptation strategies or policies, which many impact assessment methods are not appropriate to do so. IPCC (2001) suggests a list of high priorities for narrowing gaps in vulnerability and adaptation research. Among them is to integrate scientific information on impacts, vulnerability, and adaptation in decision making processes, risk management, and sustainable development initiatives. In this respect, this component of the proposed research will focus on methodology development to link impact assessment with sustainability evaluation assisted by multi-criteria policy analysis and multi-stakeholder consultation in the study region.

However, it should be noted that in this paper, not all the research activities shown in Figure 2 are covered with the same detail. Rather, focus is on the main concern of the study: design an integrated assessment approach. In this connection, the following presents the IA system assisted by analytic hierarchy process (AHP), a multi-criteria decision making (MCDM) technique, to illustrate how sustainability and vulnerabilities can be represented in the analytical system.

Multi-criteria options evaluation (MCOE) of adaptation measures is one of the major components of the proposed study. The MCOE will be used to identify desirable adaptation measures by which decision makers can alleviate the vulnerabilities and to take advantage of positive impacts associated with climate and socio-economic changes in the region.

To select desirable measures among alternatives, multi-stakeholder consultation (MSC) and MCOE will be used to relate impact information to decision making requiring subjective judgement and interpretation. In this study, alternative options will be evaluated by relating their various impacts to a number of relevant sustainability indicators. The results of various impacts generated in vulnerability assessment will be used as references for ranking the performance of each adaptation option against each sustainability indicator. These indicators are used as multi-criteria by which the strengths and weaknesses of the various adaptation options can be evaluated. The analytic hierarchy process (AHP) developed by Saaty (1980), a multi-criteria decision making (MCDM) technique, will be adopted to develop an adaptation evaluation tool to identify the priorities of sustainability goals/indicators, and to rank desirability of adaptation options (Yin, 2001).

The approach AHP takes is to ask stakeholders to determine his/her preference between two options of how it contributes to each criterion (sustainability indicator) given certain impacts of the options. In this exercise, a stakeholder compares two options at a time (pairwise comparison). Then stakeholders will specify their judgements about the relative importance of each option in terms of its contribution to the achievement of the overall goal. That is, in the case study, to

alleviate the adverse consequence of climate and socio-economic changes. It is expected that the AHP method will provide an effective means for the synthetic evaluation of general performance levels of alternative adaptation options based on a multitude of evaluation criteria. The result of the AHP is a prioritized ranking indicating the overall preference for each of the adaptation options in improving regional sustainability.

Yin (2001) developed an IA approach, assisted by AHP, to evaluate a number of adaptation options that could be undertaken to reduce vulnerabilities associated with climate change in the coastal region and communities of Georgia Basin (GB) in Canada. The AHP application in the GB study included a series of workshops and internet based surveys with participation of a broad range of public and private stakeholders, and policymakers from different affected sectors to identify sustainability indicator priorities, as well as a series of desirable adaptation policies. The AHP facilitated the participation of regional stakeholders in climate change impact and adaptation option evaluation. Results of the AHP analysis are presented in the project final report (Yin, 2001). The AHP application can improve our understanding of the interactions between regional sustainability and climate and socio-economic change impacts.

5 Expected Results

Expected results from this study will provide information to improve decision making in sustainable tourism and natural resources management in the study region. The project will evaluate and enhance sustainable tourism, water, and resource management strategies for this mountain region. Four priority areas are suggested for detailed assessment:

1) Retreat of glaciers, with potential implications for tourism sector, water resources, and biodiversity;
2) Intensification of tourism and economic development, with potential implications for regional sustainability;
3) Changes in water resources due to factors such as climate change, increasing permanent population and tourists, and/or increasing resource uses, with implications for sustainability; and
4) Recommendations of desirable and practical adaptation options and/or policies to effectively handle impacts of climate and economic changes, and to ensure sustainable development.

Training workshops will be undertaken by as many local scientists as possible. In partnership with scientists from Hong Kong University and University of British Columbia, the project can provide valuable assistance to enable local scientists to conduct high quality research in integrated assessment.

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