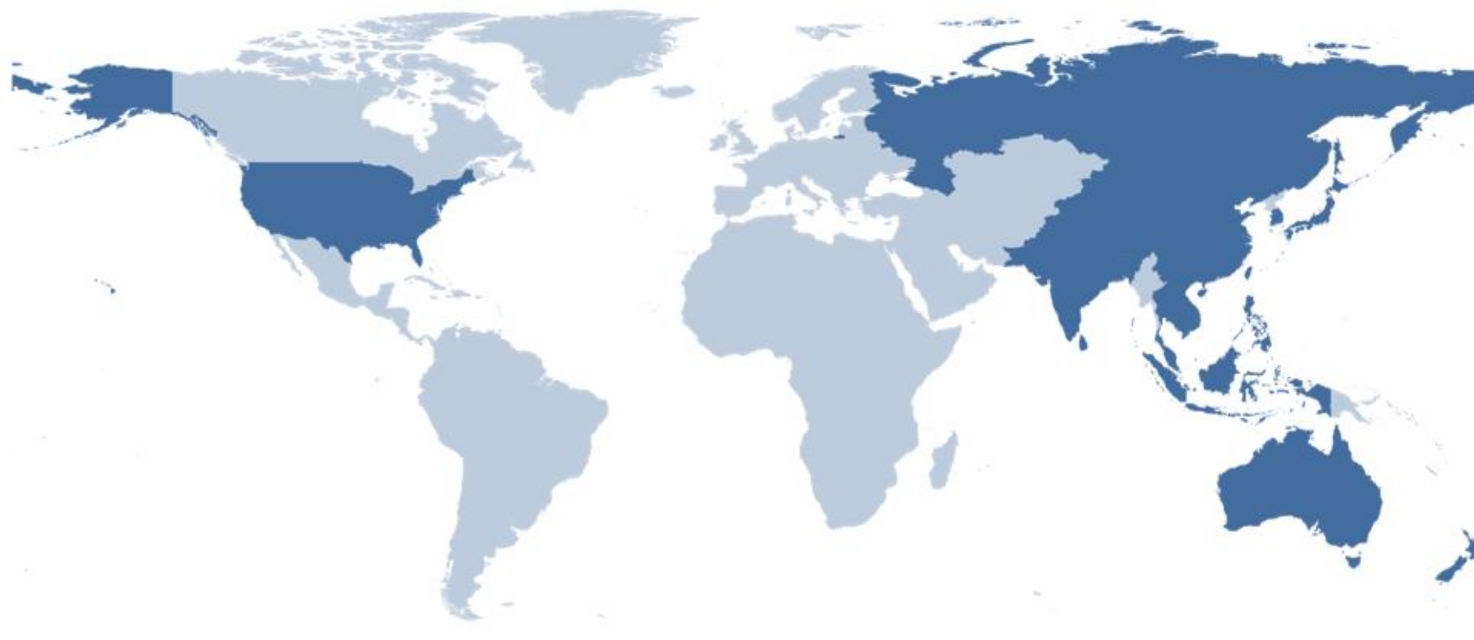
ASIA-PACIFIC NETWORK FOR
GLOBAL CHANGE RESEARCH

Project Reference Number: ARCP2013-03CMY-Herath

Developing ecosystem-based adaptation strategies for enhancing resilience of rice terrace farming systems against climate change



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UNU-IAS
Institute for the Advanced Study of Sustainability

Project Refence Number: ARCP2013-03CMY-Herath

Developing ecosystem-based adaptation strategies for enhancing resilience of rice terrace farming systems against climate change

Final Report Submitted to APN

Part One: Overview of Project Work and Outcomes

Non Technical Summary

Rice terrace systems in Asia have evolved over thousands of years into beautiful landscapes giving rise to rich cultural practices. However, some complex combination of challenges now confronts the survival of the rice terraces and its communities. The research initially focused on structural stability of Ifugao rice terrace systems in the Philippines and the Hani rice terrace system in China. However, in response to needs identified, the project expanded to take a holistic approach considering not only ecological resilience but also societal and economic resilience.

For the Hani rice terraces in China, a strategy centred on ensuring water security is proposed to promote equitable and sustainable development. Development of physical infrastructure in the form of upstream water ponds and establishing institutions to regulate and protect groundwater in downstream are proposed to achieve this.

For the Ifugao terraces in Philippines, an integrated approach through traditional Muyong forest management supported by REDD+ funding is proposed for livelihood enhancement and for managing water. Early warning of slope stability and rainfall forecasts systems installed in the study site will be used to continuously enhance local capacity for climate information use and improve understanding of the ecological functions of the terrace system.

Keywords [5 maximum keywords]

Rice terraces, adaptation strategy, land use change, water management system

Objectives

Goal: To develop ecosystem based adaptation measures and provide a generic method to strengthen resilience of traditional rice terrace farming systems in the Monsoon Asia region, reducing risk of flood and drought, through case studies in the Hani rice terrace, China and the Ifugao rice terrace, Philippines.

Aim:

1. Analyse and evaluate the ingenious and indigenous rice terracing system and technologies of the Hani and Ifugao rice terraces, especially its unique water management system which is harmoniously designed to suit the local ecosystem and plays a special ecological function.
2. Investigate and identify the current water cycle and hydrological processes in the Hani and Ifugao rice terrace watershed, and simulate its future change and uncertainty due to climate change.
3. Advocate on-site measures to address enhanced flood and drought conditions expected from future climate change. These measures will be designed to cope with future climate uncertainty.
4. Develop training modules for communities and local government officials, as well as higher education sector to develop adaptation strategies for rice terrace ecosystems in the Asia Pacific.

Amount Received and Number of Years Supported

The Grant awarded to this project was: US$130,000

US$ 45,000 for Year 1; US$ 45,000 for Year 2; US$ 40,000 for Year 3.

Activities Undertaken

- Inception workshop (partners, invited scientists, and APN) to finalize agreement on study sites and catchments, project and research strategy and 3-year plan, including a Policy Action Plan and Communications and Network Plan.
- Assessments of traditional measures in ecosystem management to reducing risk of floods and drought, collection and survey of relevant parameters for hydrological model and climate projection model, projection of worst and average changes in water cycle and increased risk of floods and drought due to climate change.
- Assessment of structural and non-structural measures to enhance ecological resilience of the rice terraces.
- Synthesis of the research results and communicating to local communities, government and postgraduate education in climate change adaptation.
- Final workshop and policy forum (partners, invited scientists, policymakers and international community) to summarize the project results and identify future steps for collaboration.
- Communications and publications.

Hani rice terraces, China

During the APN project period from 2011 to 2015, several field surveys have been conducted in the two sites. During the survey, the study sites of observing hydrological and weather data were selected. The land uses in the village, the water use system, the rich biodiversity of the forests, the sacred plots, and the world-famous rice terrace landscape at Laohuzui, Panzhihua and Badascenic spots are visited and surveyed too.

In the year of 2012, a field trip facilitated the instalment the auto weather station at Quanfuzhuang village, Yuanyang County, Yunnan Province of South-western China, which is the location of the study area as well as in Kiangan clusters in Ifugao. A water weir was constructed to measure the stream flow, with Habo water level reader as well as the installation of water meters at Quanfuzhuang village.

In the year of 2013, some 64 soil samples of rice terraces located at Qingkou village were collected, surveyed the manmade channels in the Quanfuzhuang river basin, and downloaded the water level data at this time. During February, reconstructed the water dam of inlet and outlet of farmer Liwenhe's rice terraces. In March, a workshop was arranged with a field trip to discuss and exchange the project results. The workshop included half day of in-house discussion and 2 days to visit and field survey in the project study site.

In the year of 2014, during 25-31 March, a field survey had been organized and the hydrological features of soils as well as social questionnaire survey on the impacts of tourism development in Hani rice terraces were conducted. In July the project progress has been discussed and field survey on water security of five villages: the Quanfuzhuang, Dayutang and Qingkou hamlets in upstream, Anfen and Feimo hamlets in downstream have been conducted.

Ifugao rice terraces, Philippines

Few terrace clusters in Ifugao terraces, Philippines have been inspected prior to selection of site. Local villagers who would participate in the pilot study gave advice and strongly influenced the site selection. Developing a water balance model to an Ifugao terrace entailed the collection and processing of local data. An Automated Rain Gauge, a Parshall flume to measure stream flow, groundwater measuring gauges in the terraces were installed to collect continuous data collection to model hydrological processes, water cycle and landslide vulnerability of the system.

Over the research project 10 field visits were made to collect data and conduct social surveys and researchers from UNU participated in 8 of them. Three in-depth studies were conducted in the terraces (a) a study on the management of the Muyong forests and for the sustainability of the terraces (b) a study on the potential to implement REDD+ funded forest management in Ifugao terraces and (c) impact of climate change on the water cycle and landslide vulnerability through numerical simulation of coupled hydrological and groundwater models under current and future climate projections.

Results

Relevance to the APN Goals, Science Agenda and to Policy Processes

Goal 1: Promoting regional cooperation on climate change adaptation measures for enhancing rice terrace farming system resilience in the Monsoon Asia. **Goal 2**: Strengthening interactions among scientists and policy makers at the policy forum and providing scientific input to policy making in climate change adaptation and implementation in paddy rice farming. **Goal 3**: Improving the scientific and technical capabilities of China and Philippine through technical assistance missions, collaboration and exchange. **Goal 4**: Cooperating with the UNU's existing University Network for Climate and Ecosystems Change Adaptation Research (UN-CECAR), UNESCO's International Hydrology Programme and FAO's Globally Important Agricultural Heritage Systems (GIAHS). **APN's Scientific Agenda**: Conducting systematic regional research focusing on the climate change challenge faced by mountainous rural communities, assessing the impact of climate change on local communities' livelihoods, and enhancing their resilience to climate and ecosystem change and food security in the marginal areas through **Policy processes**: Contributing to sustainable management of rice terrace systems, integrating scientific models with traditional knowledge in water management in adapting to climate change, and developing training modules for extension of the new knowledge generated from the project for local government officials, communities and higher education in development of climate change adaptation strategies.

Self-evaluation

1. The project was very successful in a number of aspects. (a) It enhanced the scientific understanding of the terrace systems clarified through field observations and numerical

modelling and a number of in-depth studies. (b) The project helped to develop a framework to build resilience through the holistic treatment of environmental, social and economic resilience of the system (c) Through the project it was possible to implement a transdisciplinary research approach that could evolve and address needs of the field and to propose measures that could bring diverse elements together, and (d) The final symposia and public policy forums helped to bring the research outcomes to all stake holders, decision makers and connected the researchers and practitioners of the two rice terrace systems, the Ifugao and Hanni to form a learning alliance.

2. The major findings of the research are as follows;
    a. Responses to climate change should not be treated in isolation, but as an integral component within overall framework for sustainable development
    b. At the local scale, different GCM projections result in significant differences in future rainfall trends. It is therefore necessary, to compare the downscaled products with past observations and correct for biases. The observed trends are higher rainfall during rainy season and longer dry periods. However, this range of variation is manageable with currently available practices provided adequate measures to address changes are taken in advance.
    c. The management of water can be the key issue to integrate diverse and independently carried out development activities to ensure cultural and environmental integrity of the rice terrace systems is maintained. Institutional as well as physical infrastructure development for ensuring water security can lead to balance development among upstream and downstream communities as well as preservation of forest cover to support both water regulation and climate change mitigation services.

3. Hold a science-policy workshop

A stakeholder workshop in the rice terraces and a science policy workshop in Manila to share experiences, make suggestions and build a learning alliance was conducted at the end of the project. (http://inate.info/sustainability-rice-terrace-systems)

4. Publish the results of the study

The project summary is published as 5 working papers and 1 policy recommendation of UNU-IAS. A number of conference and journal articles have been published. Several other publications are being prepared.

Potential for further work

Implementing the recommendations identified in the study is an important aspect of future work.

a. Identifying some potential entry points for each strategy is crucial in ensuring that policies are relevant and effective in addressing the impacts of changing climate to the rice terraces. For this end, it is proposed that (a) academics are nominated to the policy making bodies of climate change and indigenous affairs and (b) start up some incubator projects incorporating all stake holders that can develop into large scale development practices. The UNU-IAS frame work INATE (International Network for Advancing Transdisciplinary Education) is a framework that can be used to implement such projects.

b. Through technology and sustainable practices, optimization of weather forecasting and modelling though inter-agency cooperation should be made compatible to traditional practices of the local communities. Scientific understanding of the farmers should be enhanced through capacity building programs.
c. Through policies, payment for environmental services such as water user's fee based on equal sharing with upstream and downstream communities can be implemented. Attractive incentives to the Ifugao people who maintain the rice terrace systems can be offered through economic interventions such as alternative livelihood programs.
d. As for policy development, support from legislative bodies is instrumental. Reviewing existing structures and integrating in various levels of planning as well as sectoral and provincial planning are important. In planning and implementation, governing laws/codes/technical guidelines or plans, policies and programs such as climate change proof should be linked to the national sustainable development plans that include conservation of the rice terraces.
e. Climate change profiling and building up common indicators for planning implementation and monitoring purposes both in local and national level should be established. Information management system and data sharing making data accessible will enable better forecasting and strategy design by participating agencies for climate change adaptation.

Publications [please write the complete citation]

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The research team is grateful to the stakeholders who participated and provided valuable inputs.

Preface

[limit to 100 words]

This research was proposed due address concerns of climate change on traditional rice terrace systems. The Hani rice terraces in China and the Ifugao rice terraces in the Philippines were selected as the study areas to compare practices and exploit learning opportunities. In both sites, long term environmental monitoring and field surveys were carried out to support modelling of hydrological processes and water management practices and their changes under future climate. The outcomes emphasize the need to adopt transdisciplinary (multi-stakeholder, multi-disciplinary) approaches to address climate change challenges within the broad framework of sustainable development.

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1. Introduction

The project entitled: "Developing ecosystem-based adaptation strategies for enhancing resilience of rice terrace farming systems against climate change" is a three-year collaborative project of the United Nations University Institute for the Advanced Study of Sustainability, Ifugao State University, Yunnan Normal University, and the University of the Philippines, supported by the Asia Pacific Network for Global Change Research (APN).

Hani rice terraces in China and Ifugao rice terraces in the Philippines are world-renowned sustainable rice terraces that have served local communities for thousands of years. However, climate change is affecting the sustainability of those ecological management systems as it brings in new dimension of continuous changes to local water cycle that would be beyond the regulating capacity of current rice terrace systems. The goal of this research is to address dual challenges of both excessive runoff and water scarcity due to climate change by providing ecosystem based adaptation measures to strengthen resilience of the study sites that can be extended to traditional rice terrace farming systems in other parts of Asia to help them cope with the impacts of climate change. On a wider scale, adaptation strategies are vital in the achievement of each country's sustainable development plans, thus this project also aims at contributing to the mainstreaming of climate change adaptation into the sustainable development goals by engaging the policy maker community and other relevant stakeholders in the process.

Specifically, it aims to: (1) Analyse and evaluate the indigenous rice terracing system and technologies in Hani and Ifugao rice terrace, 2) Collect past and current hydrological observation data in the Hani and Ifugao rice terrace watersheds to investigate and identify the current water cycle and hydrological processes, 3) Analyse changes in the current water cycle and future water cycle change tendency using a hydrological model, in order to understand the differences in the current and future water change and distribution, 4) Identify, assess and promote on-site measures, including traditional and new measures to reduce the projected variation range in the water cycles under both the worst and average projections of future climate scenarios, 5) Conduct water analysis and related policy analysis and examine strategies on enhancing water security in the Hani rice terraces, 6) Analyse and evaluate the potential for CO_2 sequestration and REDD++ programmes to support management of muyong forests in Ifugao, and 7)Develop training modules for local government officials and communities as well as for postgraduate education and distance learning on climate change adaptation.

2. Methodology

The original objective of the project was to develop ecosystem services based approaches to mitigate potential adverse impacts of environmental changes resulting from climate change. However, in the first inception meeting itself, it became clear that the environmental and social systems in the traditional rice terrace systems and closely interconnected and treatment of one or the other in isolation will not lead to sustainable solutions. The most important outcome of the inception workshop was the agreement by all parties to consider the linkages between natural science (hydrological processes, weather), social and economic systems, and their effects under climate change. The design of physical structures such as water collection and infiltration facilities for the sustainability of the ecosystem as well as enhancing livelihoods through efficient design and governance of water management system were set as the broad objectives. This enhanced project concept will have resilience building as its core objective.

Resilience building needs to be viewed holistically considering various challenges and identifying approaches that build resilience in various sectors. In this research we adopt the frame work shown in Figure 1, (Herath, 2011) where the global change challenges such as climate change, land cover change, population increase, economic growth targets and globalization are viewed as drivers that bring about challenges. They are to be addressed by strengthening ecological, social and economic resilience of the system. In this research we addressed the (a) ecological resilience through the integrated water resources management considering surface and ground water resources, and landslide risks from extreme rainfall events, and (b) social and economic resilience through study of institutional needs for water security and economic benefits from REDD+ support to manage traditional forest systems.

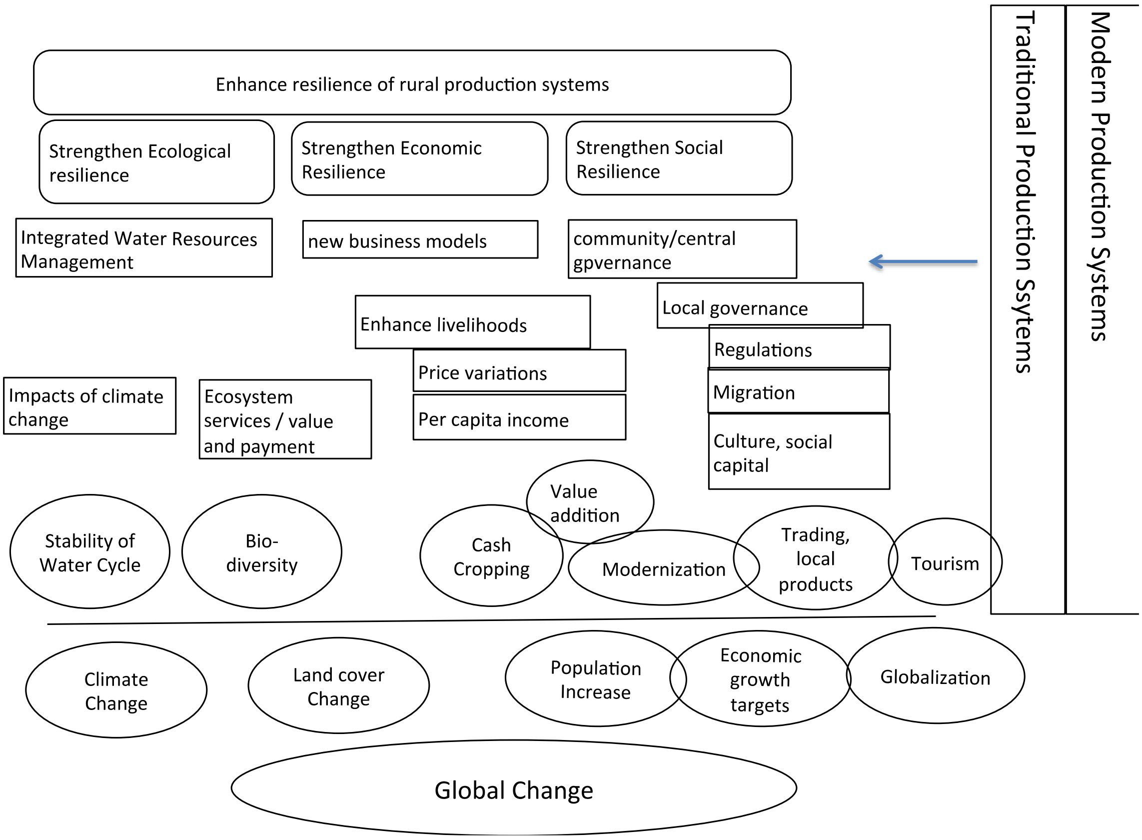


Figure 1 Framework for developing strategies for building resilience in rice-terrace systems

For individual in-depth studies, a general framework shown in Figure 2 is adopted. In general, future scenario is established according to social, land cover and weather projections. The weather is generated from downscaled future climate scenarios. At each stage verification of model forecasts is carried out as much as possible, according to availability of observations. In both study sites, in addition to collecting environmental and socio-economic data for setting up and calibrating forecasting models, extensive surveys were carried with individual farmers and focus groups to understand their aspirations, challenges and needs.

In addition to the analysis of water security in Hani rice terraces and vulnerability to landslides in the Ifugao terraces, the CO_2sequestration potential of different forest types were investigated in Ifugao to identify potential climate change mitigation initiatives.

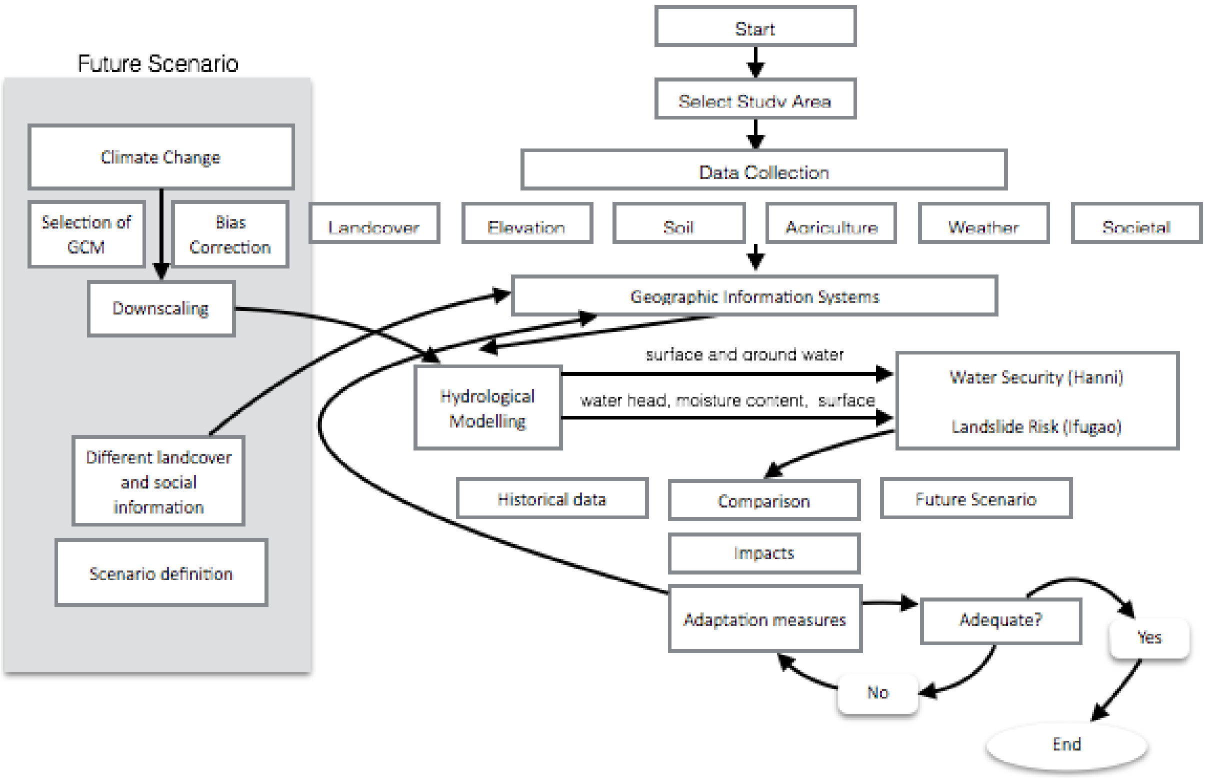


Figure 12 Framework for designing adaptation measures

3. Results & Discussion

IFUGAO

The results from the Ifugao rice terrace study are summarised in 5 sections as follows,

- Overview of environmental, socio-economic challenges
- Climate projection selection and downscaling
- Instrumentation and hydrological cycle
- Landslide risk analysis
- Assessing CO_2 sequestration potential to benefit from REDD+ support for the traditional forests

3.1 Overview of environmental, socio-economic challenges

The Ifugao rice terraces in the Philippines, one of the world-renowned sustainable rice terraces carved into the mountains of Cordillera by ancestors of the indigenous people, have served local communities for many hundreds of years. The terraces are located approximately 1,500 meters above sea level and cover 10,360 square kilometers of mountainside. The Ifugaos adopt a strict land use pattern for long-term sustainability of rice terraces. Rice terraces are cultivated below the forests called muyong and form an integrated landuse pattern. The muyong forest are private woodlots but are sustainably managed with assisted natural regeneration to ensure watershed service to the rice terraces below. Shifting cultivation is practiced to produce other crops above the muyong forests. The Ifugao terraces of the Philippine Cordilleras were listed as a World Heritage site by the UNESCO World Heritage Centre in 1995. As they are dependent on complex water management and vulnerable to weather and climate patterns, changes in climatic conditions have significant impacts that threaten the sustainability of these ecological management systems. This requires quantitative assessment of changes and resulting impacts and then to devise appropriate strategies to address them. In order for an appropriate strategy to be devised, an intervention must also take into account the relevant stakeholders aspirations and societal conditions that are specific to the project site. Safeguards must take into account the existing situation within the area and within the country. The social and environmental issues of the area is an extremely complex to address. The primary problems in the area are largely a result of economic pressures.

The change to the intensive use of commercial rice, in particular, has been a large factor in contributing to this change. The introduction of the high yielding varieties of rice under the Green Revolution Program of the Philippine government in the 1970s substituted the heirloom Ifugao rice varieties to the native 'tinawon', which delivered double or even triple of the usual once a year harvest. The traditional farmers readily shifted to the high yield varieties from the government's 'revolutionary development initiative. After the farmers have grown accustomed to its perceived benefits, the traditional knowledge that comes with the cultivation of the native 'tinawon' eventually is forgotten, threatening the Ifugao intangible culture aside from the other more prominent negative physical results of the initiatives in the rice terraces. Interventions such as this while addressing the very important economic issue, has not considered its effect on practices surrounding the native 'tinawon' which are central to the Ifugao belief system, and critical to the sustainability of the rice terrace systems.

"Without the customary practices that necessitate their accompaniment, the rich and complex oral tradition of the Ifugao will cease to exist sooner than later. Non-contextual performance of cultural rituals only reflects the desperate state of conservation in the rice terraces." – Marlon Martin, SITMo

With the HYVs having no ritual value whatsoever, rice rituals have ceased to be practiced. Further, one no longer hears the chanting of the hudhud epic, during planting or harvesting of the tinawon rice. This UNESCO-declared Masterpiece of the Oral and Intangible Heritage of Humanity is currently being taught to children in primary schools as a last-ditch effort in intangible heritage conservation. Communal practices that revolved around the traditional agricultural cycle have lost their meaning resulting to sudden changes in the socio-cultural makeup of terraces communities. Customary labor practices and gender roles changed as a result of the changing of rice varieties in the terraces- an effect never perceived by any of the development agencies involved in the shift to lowland rice.

The farmers also were critical of the implementation methods adopted in the restoration works. In Batad, Banaue, millions of funding are paid by the government to the farmers to repair their own damaged walls, but this has created a psychology of dependence among the community that focuses more on the quantity rather than quality as the priority of the stonewall builders. Ancient underground canals which were damaged during landslide were merely backfilled instead of proper restoration since there are no professionals that oversee proper conservation and restoration work. These problems arise when modern development projects are implemented without proper understanding of the traditional or customary features of the landscape and consultation with the local people.

These complaints makes one feel that making the traditional rice terrace farming systems economically viable, vibrant cultural centres is a challenging task that demand integrated approaches. A ten-year Ifugao Rice Terraces Master Plan, introduced in 2002 delineating the functions of all stakeholders with each a particular function, sought to centralize all initiatives on the conservation work on the IRT at least at the provincial level. However due to bureaucracy and lack of inter-agency coordination, the delivery of the services was not successfully implemented and felt by the local community.

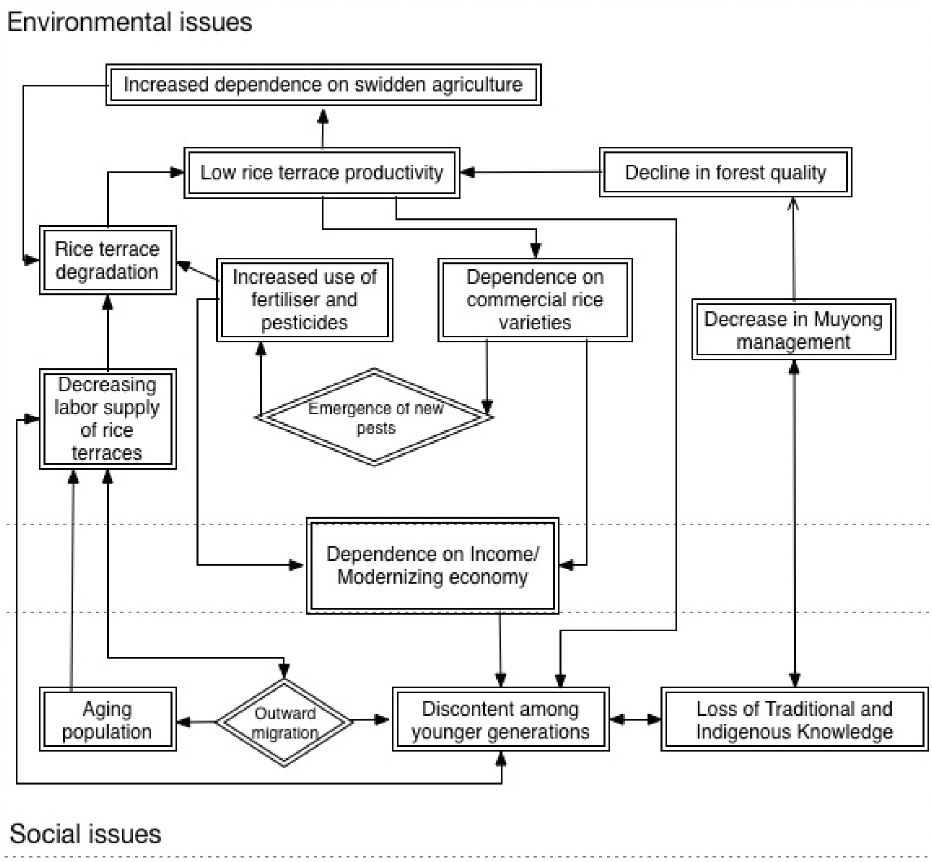


Figure 3 Various difficulties faced by the Ifugao community as identified during field visits and surveys

In the present study promotion of traditional forests 'muyong' management is investigated as an integrated approach that can improve the livelihoods of community, support water regulation functions under future climatic extremes and provide a mechanism for reducing landslide risks. The creation of non-carbon benefits associated with a REDD+ initiative looks for an intervention to actually improve the livelihood of the local communities in addition to sequestering carbon. The promotion of the concept of the *muyong* seeks to do just that as the *muyong* provides essential ecosystem services that enhance the livelihood of its users

3.2 Climate projection selection and downscaling

To understand farmers' perception of climate change, focus group discussions with local farmers residing in Bayninan village were conducted. Specifically, farmer perceptions on climate change impacts, and local adaptation measures and behaviours were obtained. Sample sizes were small due to the small population in the village. Thus, results were synthesized from qualitative content analysis of the answers, rather than quantitative statistical methods. Such information is valuable in that it can also be used to check if downscaled Global Climate Model (GCM) projections actually match the observations of the locals.

All participants have heard the term “climate change”, primarily through mass media such as television and radio. The interviewees have a combined total of more than 100 years farming experience. The trust rating attributed to media in terms of climate change is “very high”, and this was because the farmers claim that they have been personally experiencing climate change in the last 15 years. Table 1 summarizes some pertinent findings on farmer perceptions about climate change, and their challenges to adaptation.

Table 1. Climate change perceptions of farmers in Bayninan

Perceived Impacts of Climate Change	Adaptation Measures Implemented	Challenges to Climate Change Adaptation
Stronger typhoons Shifting of rainy and dry seasons Stronger thunderstorms Reduction of stream flows Increase in pest occurrence	Shifting the cropping calendar Reducing water input during dry season Repair of irrigation and drainage canals Application of fertilizer	Lack of money Lack of information Lack of technical skills Lack of labor

It is necessary to transform the global scale and statistical characteristics of climate information from GCMs to local scale and weather information for the farmers to make use of the information, and for the project team to assess the impacts on the terraces. We have assessed the validity of the GCM forecasts through comparisons with the past observations, and also assessed the skill in forecasting present weather using a numerical weather forecasting model (WRF model) calibrated for the site.

For the GCM model selectio, models included in the Coordinated Regional Downscaling Experiment (CORDEX) East Asia database (https://cordex-ea.climate.go.kr/) were investigated. These regional climate projections (~50km resolution) are based on a family of GCM’s developed by the Met Office Hadley Centre called HadGEM2-AO. The data used here are the results from by the Korean Meteorological Administration (KMA) and the National Institute of Meteorological Research (NIMR). For comparison, global precipitation outputs (~120km resolution) from the GCM of the Meteorological Research Institute (MRI) of Japan, as included in the 5th Coupled Model Intercomparison Project (CMIP5), were also investigated. The RCP’s considered were RCP 4.5 and

RCP 8.5. RCP 4.5 is a stabilization without overshoot pathway to 4.5 W/m^2 at stabilization after 2100, through the use of various policies and technologies to minimize greenhouse gas emissions (Thomson et al., 2011). RCP 8.5 is characterized by comparatively high greenhouse gas emissions and absence of climate change policies resulting to a radiative forcing of 8.5 W/m^2 in 2100 (Riahi et al., 2011).

Figure 4 shows the comparison of the observed rainfall data to the different model outputs for the period of 1981-2005. Note that RegCM4, SNU-WRF, YSU-RSM, and HadGEM3-RA, are regional climate projections derived from the HadGEM2-AO GCM under the CORDEX project.

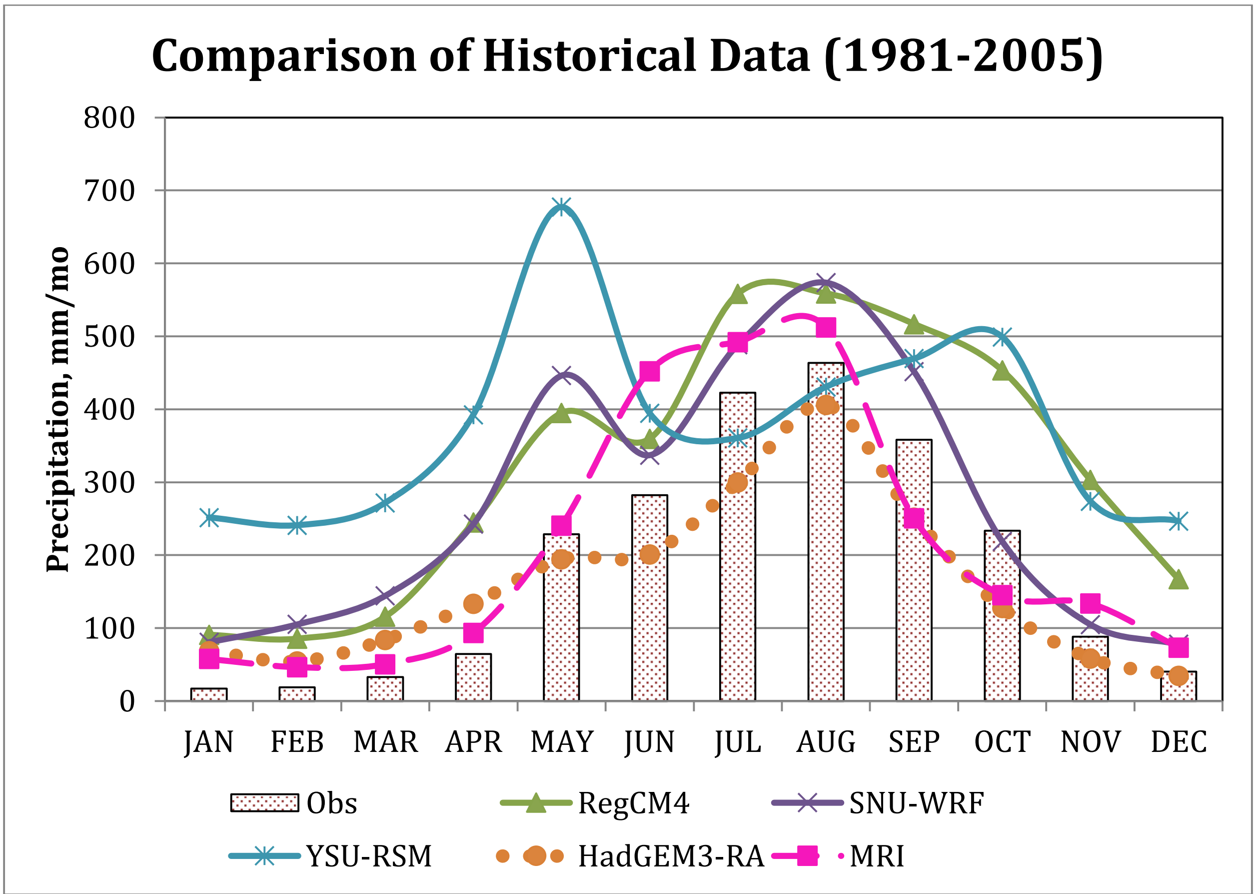


Figure 4. Comparison of observed data and raw model outputs for 1981-2005 period

It can be seen from Fig. 4 that there are considerable biases between observed data and raw model outputs. Furthermore, two models, namely HadGEM3-RA and MRI are able to capture the seasonal rainfall trend better than the other models. These two model outputs were then corrected using quantile-quantile (gama distribution) method. The bias output from MRI and HadGEM3-RA projections tend not to agree with one another very much. However, the projections generally indicate less rainfall for the dry season. MRI projections showed a future rainfall trend consistent with the expected changes from climate change.

According to the outcome summary of the IPCC WG1 in the AR5, the total concentration of CO_2 will determine the temperature increase, and thus the change of climate conditions. Thus, RCP 4.5 in the far future and R 8.5 in the near future are expected to provide similar results. This is clear from a comparison of MRI 4.5 projections trends estimated from 3 point moving averages of monthly rain for the year 2091-2100 (FF) and the MRI 8.5 projections for the 2041-2051 (NF) shown in Figure 5.

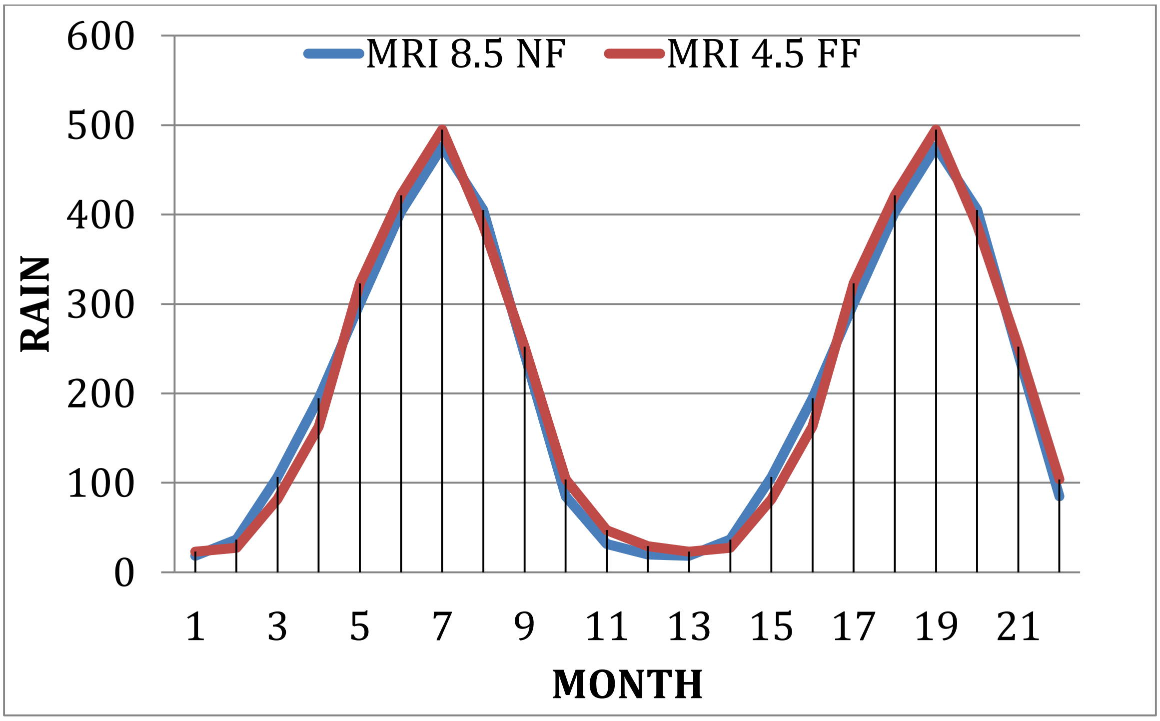


Figure 5. Seasonal rainfall (moving average for 3 months) of the MRI model show identical patterns for the RCP 4.5 far future and RCP 8.5 near future scenarios

To understand the trends in rainfall change the monthly rainfall values smoothened with a 3 point moving average of the MRI 4.5 and MRI 8.5 projections for the near future (NF) are compared with the current (historical) rainfall shown in Figure 6. Compared to present, the rainy season will start late and will last longer under the RCP4.5 scenario. There will be no significant increase in the month to month rainfall values. Under RCP 8.5 (or far future under RCP 4.5) there will be a significant increase of the rainfall during the peak rainy periods of June and July, but less rainfall during October to February season.

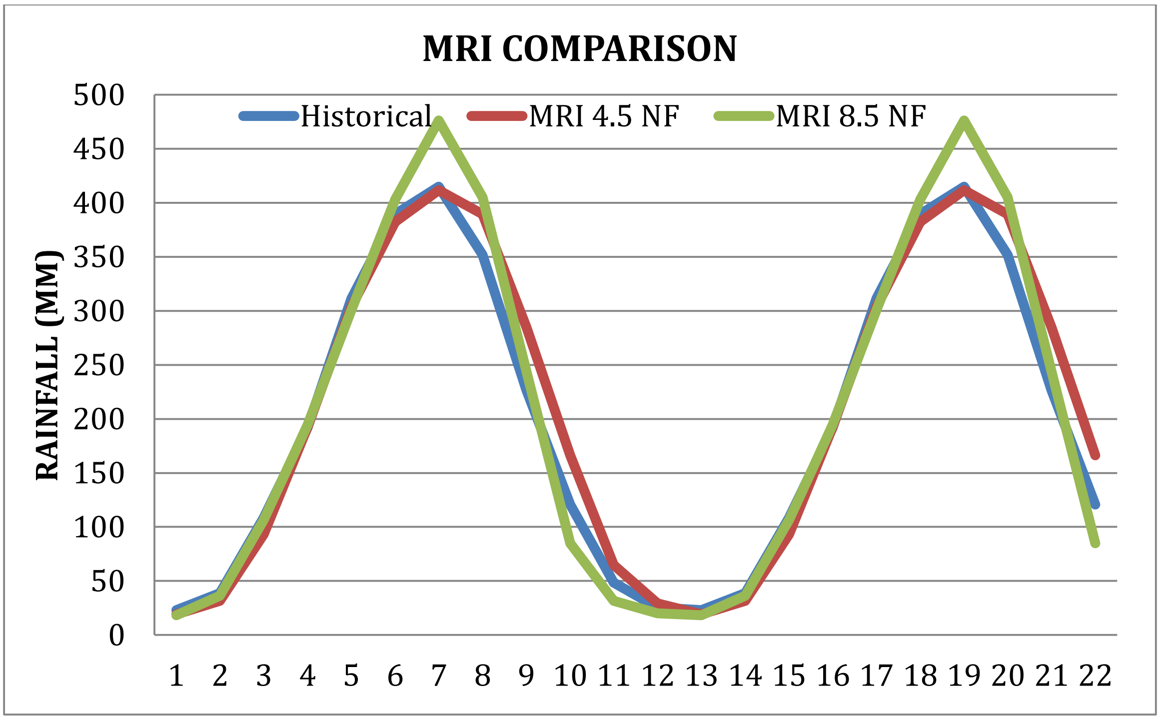


Figure 6. Comparison of MRI projections with historical trends

3.3 Instrumentation and analysis of hydrology

A series of simple falling head infiltration tests to measure infiltration rate within the rice paddies has been collected. As reported by Reynolds (2013), these single-borehole infiltration tests are widely used for measuring the field-saturated hydraulic conductivity. Figure 7 shows the most common configurations for the test. The adopted configuration is as shown in case D. Combined vertical and radial discharge from a cased borehole with a basal gravel pack. Reynolds reports that for this configuration, highest accuracy is attained when $0 \leq L/H \leq 1$. A representative infiltration curve obtained from the field is shown in Figure 8.

Groundwater observations

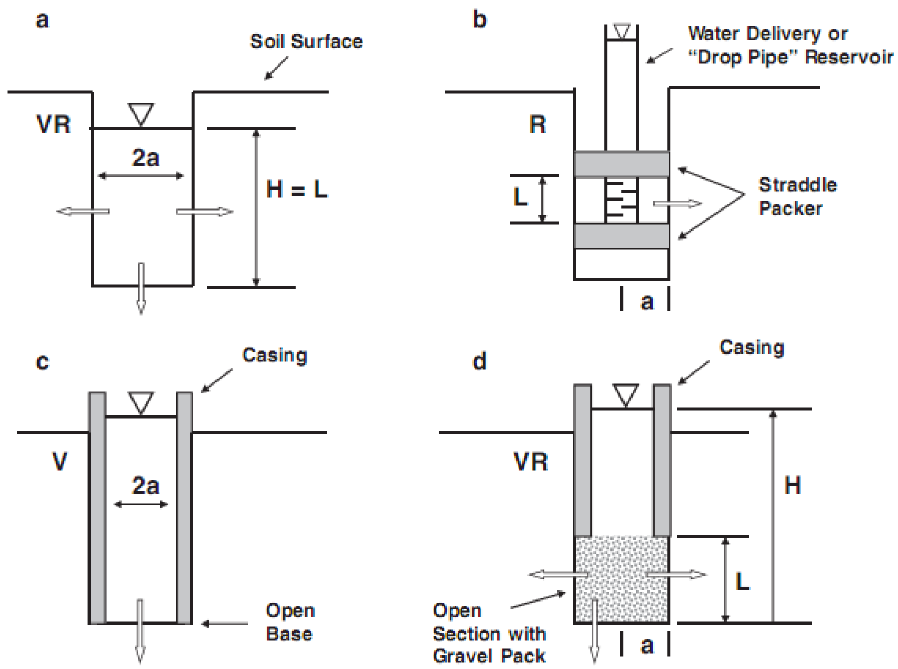


Fig. 1. Common borehole configurations for conducting single-borehole infiltration tests: a) combined vertical and radial water discharge (VR) from an uncased (open) borehole; b) radial water discharge (R) through a straddle packer installed in an uncased borehole; c) vertical water discharge (V) from a fully cased borehole; and d) combined vertical and radial discharge (VR) from a cased borehole with a basal gravel pack. H = water ponding depth; L = length of water discharge zone; a = radius of water discharge zone. Block arrows indicate directions of water outflow through discharge zone.

Figure 7. Common single borehole infitration test configurations (Source: Reynolds, 2013)

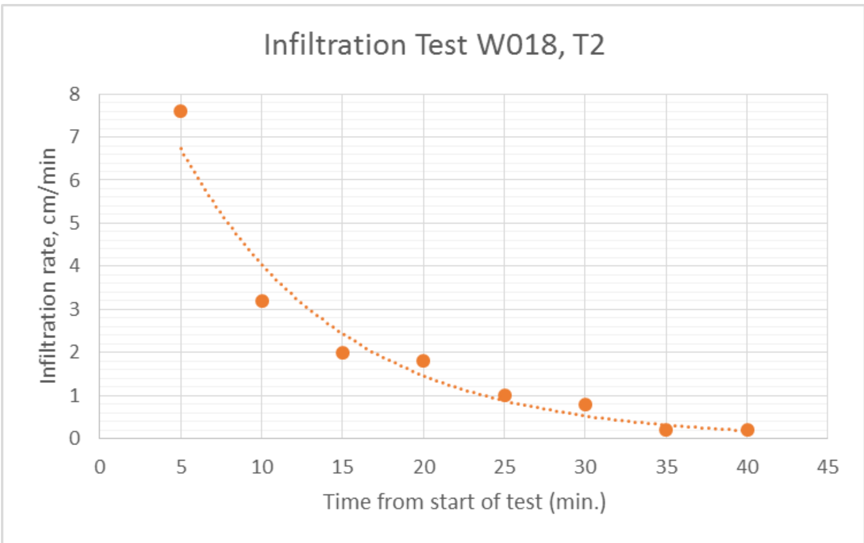


Figure 8. Infiltration curve from waypoint W018

For long term observations an automated rain gauge, a Parshall flume for discuarge measurements and seven field water tubes and three groundwater observation tubes were installed according to the specifications of the International Rice Research Institute (IRRI). These tubes are effectively piezometers. which indicate water levels. IRRI recommends them for investigating availability of water to crops. The water levels also provide useful information for calibrating hydrological models. Figures 9 and 10 show the IRRI specifications and the installed observation tubes in the field.

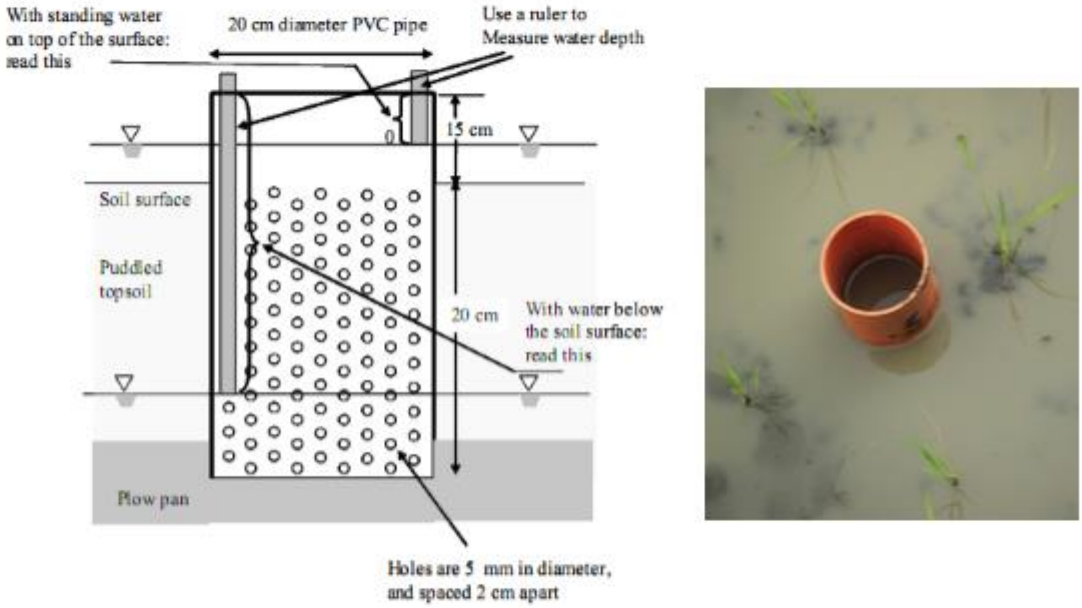


Figure 9. Field water observation tube: Right- IRRI specifications; Left- Installed tube in-situ

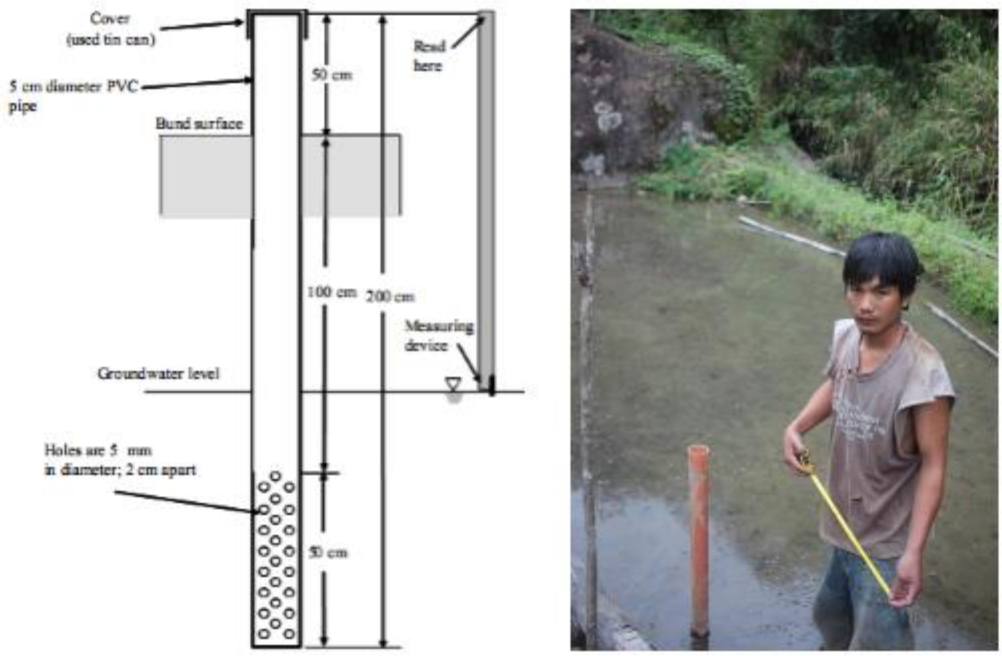


Figure 10. Groundwater observation tubes: Right- IRRI specifications; Left- Installed tube in-situ (shown in photo is Mr. Sherwin Olnanigon, our local data recorder)

Figure 11 shows the records from one of the groundwater observation tubes. As stated earlier, only preliminary insights can be formulated due to the short observation period. It can be seen that groundwater levels generally decrease in the dry season (up to May), somewhat stabilize in the wet season (June to September) then increase again in the last months of the year. This type of behaviour is common in climatic zones with pronounced single wet and dry seasons. During the dry season, much of the groundwater is depleted either by uptake from the root zone (to satisfy crop water

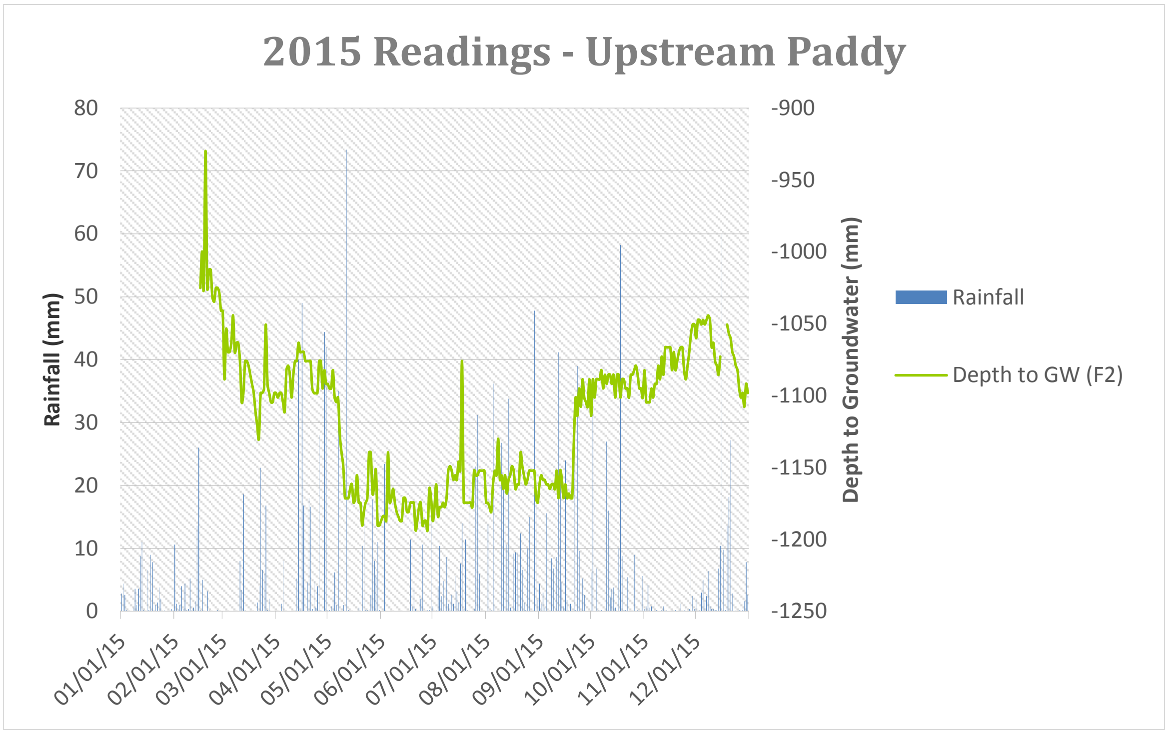


Figure 11. 2015 Rainfall (left axis) & Groundwater observations (right axis)

requirements in the lack of rainfall or surface irrigation), or aquifer discharge in the form of baseflow. Recharge to the aquifer is limited in the dry season, so groundwater levels continue to decrease. In the wet season, rainfall satisfies much of the surface water requirements, such that the groundwater system more or less stabilizes. Aquifer recharge also increases with rainfall, although the groundwater system responds with a considerable time lag. This explains why groundwater levels only increase later on in the wet season.

Paddy field water level observations

Figure 12 shows collected data from the seven field water observation tubes, along with the 2015 rainfall recorded by the ARG. Although the observation period is short, and concrete conclusions cannot be formulated yet, some preliminary insights can be drawn. On average, water level in the rice terrace paddies fluctuates between 100 to 150 mm. This is higher than the ponded depth of 50 mm reported by Dulawan & Liongson (2011), although 50 mm appears to be the minimum value attained in some periods. The maximum value is approximately 280 mm, which curiously occurs in the dry season (March/April). According to the local farmers, these sudden peaks represent days when irrigation water was diverted from streams directly into the paddies where the observation tubes were located. It must be noted that these periods also correspond to the maturity stage of the rice crops in the traditional agricultural calendar, when the crops require the most water. Meanwhile, the lower values of ponded water in the terraces also curiously correspond to wet season months (August/September). The locals report that this can be explained by the widening of the drainage canals and inter-terrace spillways which is usually undertaken after harvest (June/July) and right before the wet season, to enable faster drainage of water in case of extreme rainfall. Minimal water is required in the terraces during this fallow period. This represents a local form of adaptation measure to deal with climatic extremes. It also highlights the need for a continuous supply of labor to perform such intensive maintenance works in the terraces and complete the required modifications in time, that is, before the onset of heavy precipitation events such as typhoons and the monsoon season. It can be surmised that such type of local knowledge has enabled the sustainability of the rice terraces to persist up to now.

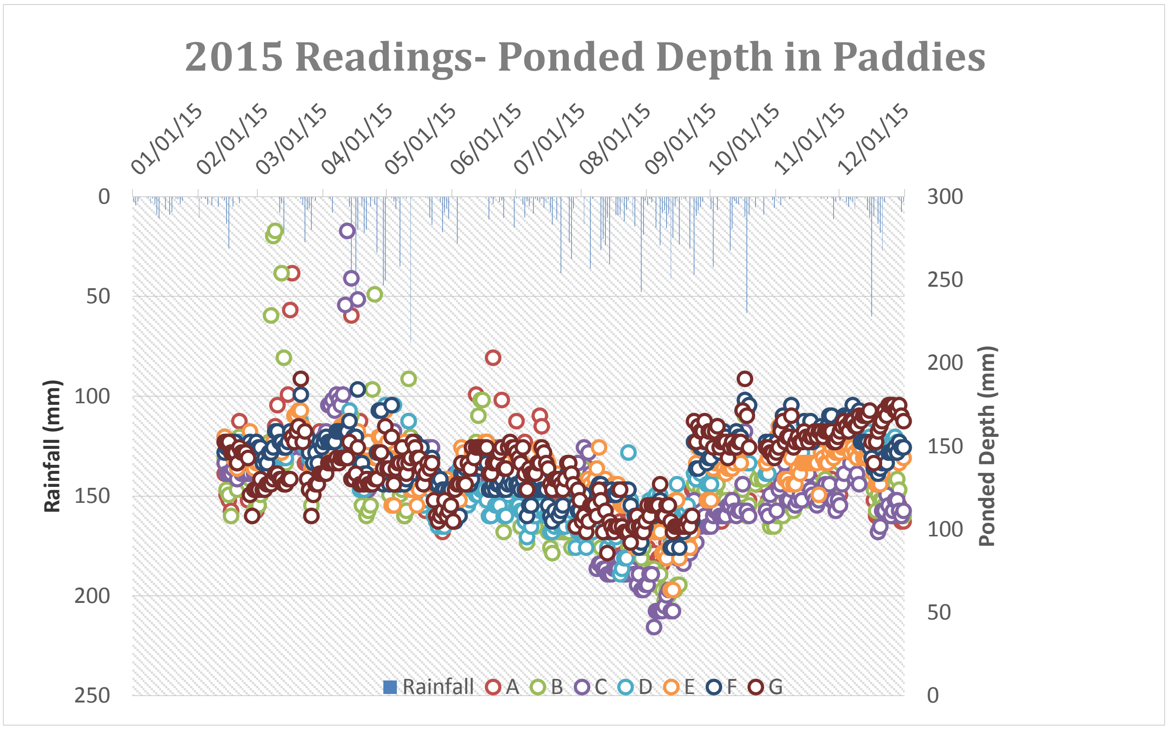
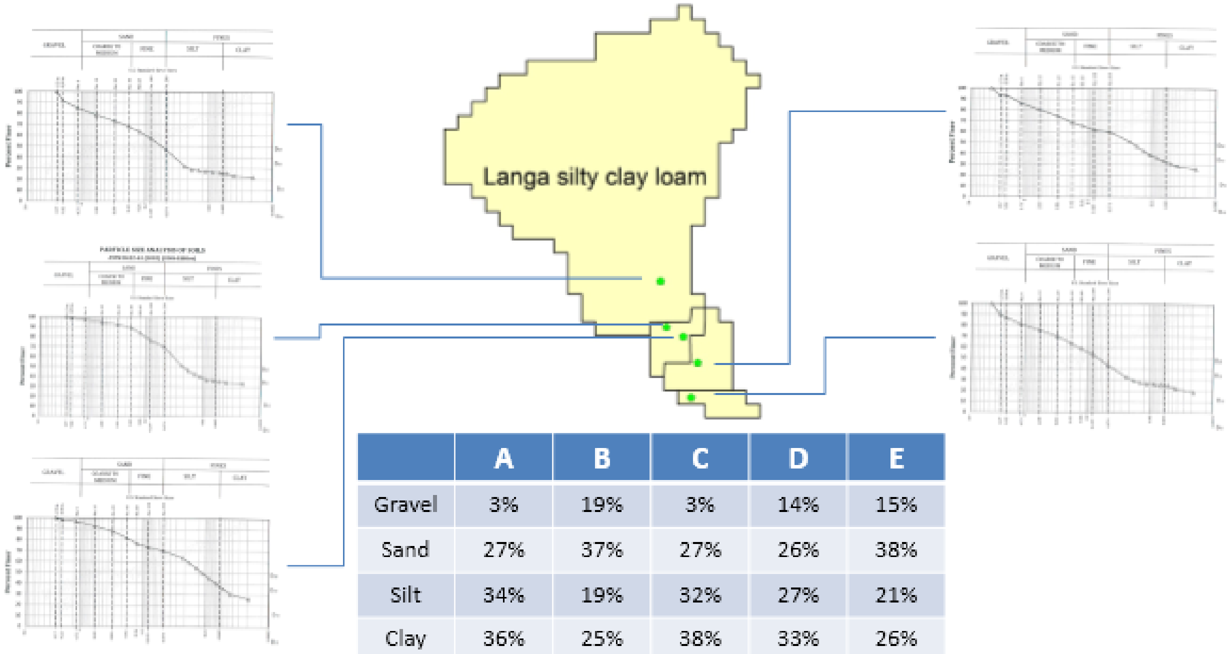


Figure 12. Rainfall (left axis) and paddy ponded water height (right axis)

Hydrological Analysis

Soil samples were taken for laboratory characterization using mechanical sieves with hydrometer analysis. Figure 13 shows the sampling locations across the catchment, along with the resulting grain size distribution curve. The soil map from the Bureau of Soils and Water Management (BSWM) classifies the entire study area into Langa silty clay loam. The laboratory results were consistent with this classification.



	A	B	C	D	E
Gravel	3%	19%	3%	14%	15%
Sand	27%	37%	27%	26%	38%
Silt	34%	19%	32%	27%	21%
Clay	36%	25%	38%	33%	26%
Spec. Gravity	2.61	2.61	2.62	2.67	2.61

Figure 13. Soil type based on laboratory analysis and BSWM soil map

Figure 14. Parshall Flume installed in the selected terrace catchment for the measurement of stream flow.

The target river in the study site is approximately 2 m wide, and has variable seasonal flows. It also carries a considerable amount of sediment load. Thus, a flume was deemed to be a suitable instrument for stream flow measurement. The flume was constructed under an existing bridge, which traverses the target stream as shown in Figure 14. It was completed and daily observations commenced in March, 2014. The streamflow measurements were used to calibrate the hydrological model.

Hydrological modeling of the site was carried out using the Similar Hydrologic Element Response (SHER) model. The study area is subdivided into homogenous SHER blocks based on characteristics of topography, soil type, slope, and land cover. The SHER model representation of the catchment in the ExtendSim modeling environment is shown in Fig. 15.

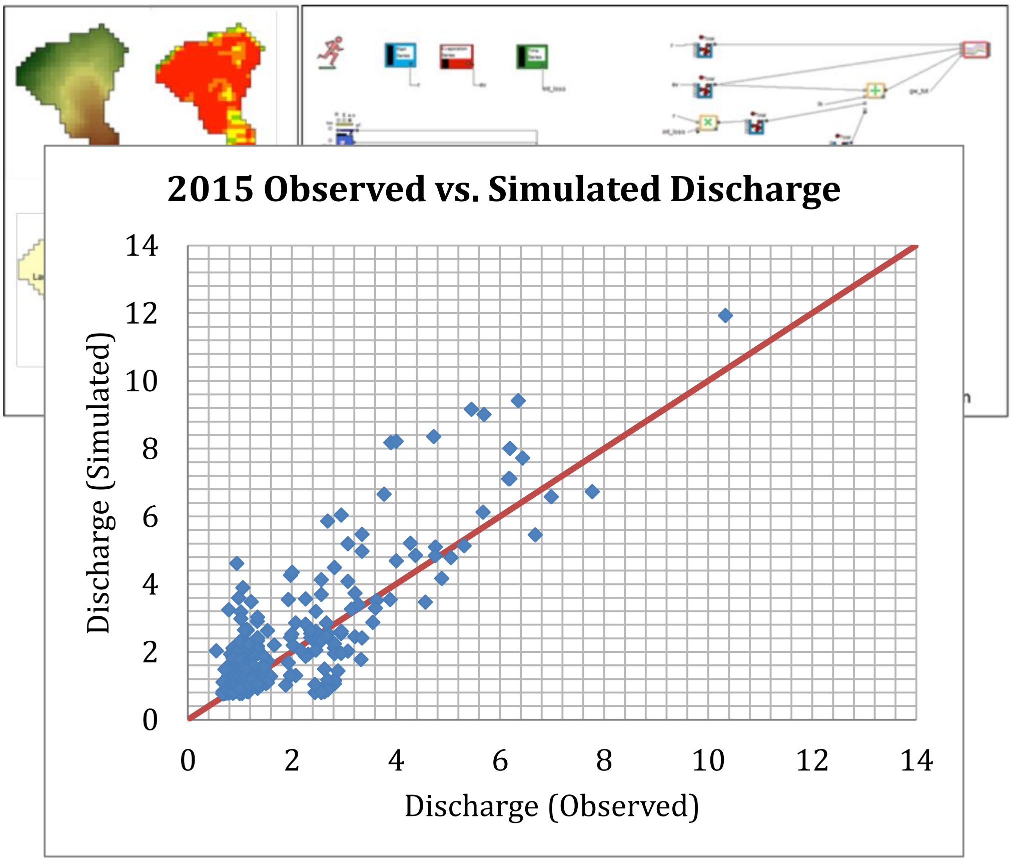


Figure 16. Observed vs. simulated discharge for 2015 data

The 2014 observed data were used to calibrate the model parameters, and the 2015 data were used to validate the model. Figure 16 shows the comparison of observed vs. simulated discharge for 2015. For the 2015 validation period, the Nash-Sutcliffe efficiency was calculated to be 0.5184.

Hydrological analysis using current and future rainfall taken from downscaled GCM projections indicates that only 70-80% of the current evapotranspiration requirements can be met in 2041-2050. For 2091-2100, only 60-70% of the current evapotranspiration requirements can be supplied. This implies a need to make adjustments either in the agricultural practices or development of physical infrastructure to retain rainwater in the upstream area that can be utilised during enhanced dry periods to augment the ground and surface water of the terraces.

3.4 Landslide Risk Analysis

Landslide risk in the Ifugao rice terrace landscape is carried out using a geotechnical slope stability model based on limit equilibrium analysis. In this module, the factor of safety is calculated, and an element is classified as either stable or unstable according to the factor of safety. The model is particularly well-suited for precipitation-induced shallow landslides, as it accounts for the dynamic state of pore water pressure changes. Slow-onset deep landslides, which are often large and caused by tectonic movements, are not covered in the model.

The recharge calculated from the SHER model is input as a boundary condition for the MODFLOW groundwater model to calculate the resulting three-dimensional head distribution. The study area is discretized into the finite difference grid shown in Fig. 17. The cells outside the catchment boundary are declared to be inactive cells. The catchment boundaries are defined to be no-flow cells, except for the bottom boundary, which corresponds to a river, and is idealized as a general head boundary.

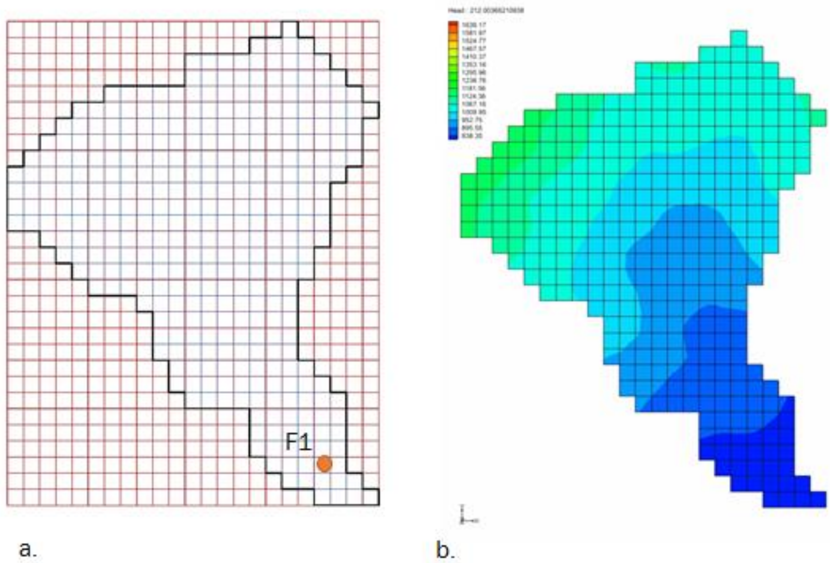


Figure 17. (a.) MODFLOW finite difference grid (b.) Simulated head distribution

The pore water pressure is calculated from the simulated MODFLOW heads is used in the geotechnical slope stability model to identify areas which are at risk of landslides. Figure 18 shows the maps of the calculated factor of safety within the study area. Areas in green are those with FS > 1.0, predicted to be stable. Meanwhile, areas shown in red are those with FS < 1.0, predicted to be unstable and therefore, at risk of landslides.

All simulations pertaining to different climatic conditions showed the same evolution of the propagation of unstable cells. Fig. 18a shows the distribution on the initial failure of slopes, wherein 4.21% of the study area has failed. Fig. 18b shows an intermediate case, with 8.12% failed slopes. Fig. 18c shows the worst case scenario, in which 35.07% of the study area was predicted to fail. As expected, the unstable cells increased with increasing pore water pressure.

The worst case scenario (Fig. 18c) occurred for all cases, meaning that climate change did not affect the spatial distribution of landslide risk. However, the number of times the worst case scenario (Fig. 53c) occurred increases due to climate change. It was seen that from once a year in 2014-2015, the number of times the worst case landslide distribution occurs increases under the climate change scenarios considered from 25 to 30 times in the near and far future compared to current frequency. This is an indication that climate change will increase the landslide risk in terms of frequency.

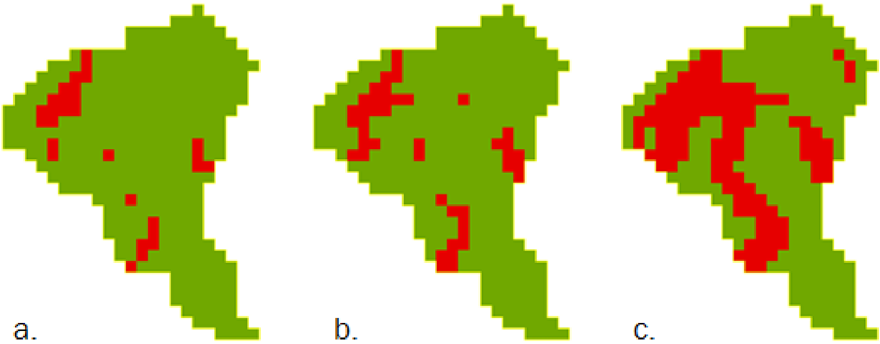


Figure 18. Distribution of predicted unstable areas within study area (green – stable; red - unstable)

3.5 Assessing CO_2 sequestration potential in Ifugao forests

The study site selected for the study is in the Barangay of Nagacadan located along the western border of the municipality of Kiangan, Ifugao Province. Nagacadan is approximately 600 hectares in size and is comprised of five hamlets: Bayninan, Wingyon, Onnop, Pau, and Bilong. A carbon study was conducted by measuring four different carbon pools of the local forests: the forest carbon stock, non-tree vegetation, forest floor litter layer, and soil carbon at 10 cm depth. A qualitative assessment was also carried out in order to assess the potential for REDD+ implementation in the area through focus group discussion and key informant interviews.

Two classifications of forest that are native to the area were used in the carbon study, the *muyong* and the *bilid*. The *muyong*, refers to the private woodlots that are maintained by residents of the area. The *bilid* is the other forest land use in the area. In the context of the local community, the *bilid* refers to the forested area along the mountain ridge. It is usually distant from the homestead and unlike the *muyong*, is communally managed. Because of the different management regimes, the *bilid* exhibits different characteristics from that of the *muyong*, most notably: forest species composition, tree density and average diameter at breast height.

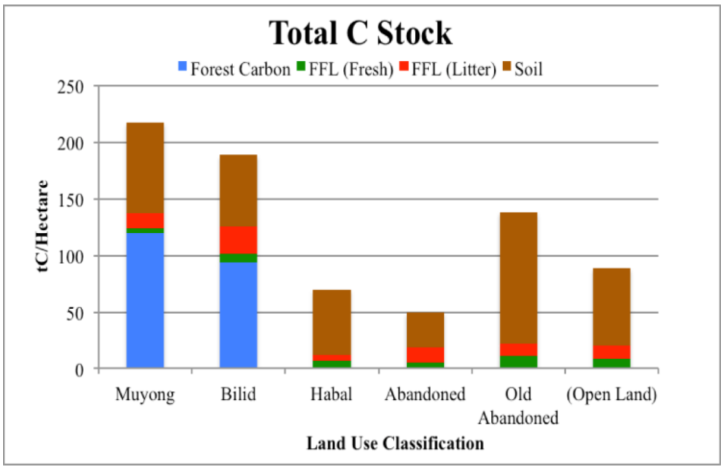


Figure 19. CO_2 sequestration potential of different forest categories

HANI

The results from the Hani study are summarised as follows

- Instrumentation to Hani terraces
- Effect of soil characteristics on terrace system
- Effect of vegetation on terrace system
- Water distribution characteristics
- Water security as the development objective

3.6 Introduction to the Honghe Hani rice terraces

The cultural landscape of Honghe Hani rice terraces is composed of the forests on the mountain top, the villages below the forests, rice terraces below the villages, and the water systems linking the forests, the villages, and the rice terraces together. Forests are maintained and protected by local government and communities. The water from the forests runs though an irrigation network to reach the hamlets and then the rice terraces, and then continues to slope downward into the river valley. The water passes though forests and carries litter, humus, surface soil, and microorganisms, becoming enriched with organic and inorganic matter, then flowing though the villages and rice terraces. The rice terraces have been shaped into neatly stacked trays, one above the other, to facilitate gravity-fed irrigation. When the upper trays have filled with water, the excess water run down into the next tier, and so on until it descends from the mountains and enters the river. Villagers can easily walk upslope to obtain firewood, many kinds of wild vegetables, herbal medicines and leaves for their livestock from the upland forests and grasslands.

The heritage site of Honghe Hani Rice Terrace is located at Yuanyang County in Yunnan Province, China. Yuanyang has a subtropical monsoon climate with an average temperature of 16.4°C and average precipitation of 1,400mm. Humid evergreen broad-leaved forests with abundant streams and ponds cover the middle mountains, while the higher mountains (those above 2,000 m) are covered by natural forests with higher water supply. The water from the forests runs through the irrigation network to reach the hamlets and then the terraces. The rocks are principally acidic rocks and granites that were generated during the Indo-Chinese epoch, and also include metamorphic rocks generated in the Triassic period. The bottom layers of these rocks are solid, leading to plentiful seepage of rainfall above the solid foundation to form rich shallow deposits of groundwater. These flows emerge as springs in areas that are lower than their surroundings. Therefore, the basin has abundant streams, ponds and springs. Rainfall is the main source of ground water recharge, while the discharge of ground water has the following features: short discharging distances, on-site recharges, and on-site discharges which are controlled by local terrain. The runoff of observed study sites during October to December was usually higher than other months, while precipitation was higher from May to August. The water balance components are precipitation, ground water, discharge, evaporation and transportation, and water in terraces, ponds, and reservoirs. The five components for storage of water are:

(a) Forest interception of rainfall concerning water vapor, rainfall, interception types (canopy, stem, shrub, grass, and litter), soil water, and run off;

(b) fog water;

(c) natural forests and ponds;

(d) reservoir and drink water pipes; and

(e) water pipes in upper reaches. The water management system uses both natural irrigation and drainage channels. The Hani also use the irrigation channels (including streams and rivers) to transport fertilizers to their terraces.

3.7 The role of soil in hydrological function of Honghe Hani rice terraces

Soil is one of the water conservation media in hydrological cycles. In this project, we took soil moisture and its water capacity as the indices of its hydrological function. The soil samples from two forest sites and one grass with a 300cm depth were collected to analyze the soil moisture and water capacity. The results indicate: The vertical change of soil moisture is impacted by soil texture and vegetation type. The coefficient of variation of Sandy soil moisture of forest is higher than clay soil of forest, and the coefficient of variation of forest is higher than grass while both soil samples are clay. Both the max water holding capacity and capillary moisture capacity at the 0-160cm depth are ordered as forest higher than grass and higher than forest, this indicate the regulation function are high of forest and grass. The water holding capacity has a significant correlation with non-capillary porosity.

We also collected 162 samples (81 of the dry season, 81 of the rainy season) on surface soil (0-20cm) of water conservation region, we analyzed the spatial variability of soil moisture on Hani Rice Terraces based on classical statistics and geostatistics method. The results indicate:

(1) Soil moisture of the dry season is moderate variation (Cv is 18.19%), the ratio of semivariogram's structure is 99.9%,the range is 383m. Soil moisture of the rainy season is moderate

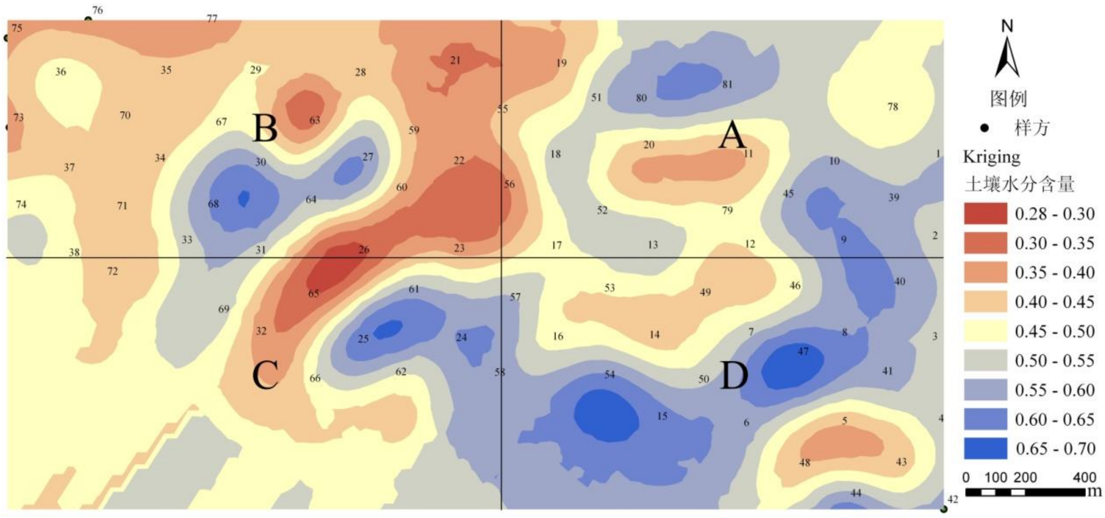
variation (Cv is 18.50%), the ratio of semivariogram's structure is 99.9%, the range is 475m,that indicate a high spatial autocorrelation of soil moisture. From the dry season to the rainy season, the spatial structure parameters of soil moisture are different, the most obvious one is the range. There is a consistency of the anisotropy, but the ratio is different.

(2) Kriging interpolation figure indicate that soil moisture's spatial pattern on the dry season came out as obvious patches with the higher fragmentation and the poor continuity of space. soil moisture's spatial pattern on the rainy season came out as stripes with the better continuity of space. The overall trend is consistent of soil moisture pattern between two seasons, but the spatial pattern of the dry season is more significant and its almost same as land use pattern.

(3) Soil moisture content and its variation are in keeping with spatial tendency on the dry season and the rainy season because they are affected by rainfall, but the response of soil moisture on the dry season is more sensitive to rainfall.

(4) Land use types are key factors which affect the heterogeneity of soil moisture, but meteorological factors(such as rainfall)can reinforce or weaken that trend. Soil moisture content is significantly correlated with elevation, but get less impact on slope gradient.

(5) Spatial and temporal variability of soil moisture can reflect differences in pattern and function of water conservation region, there is a great significance to identify the key areas of water conservation features, protect the pattern of ecological security, maintain the balance of water supply and the stability of terrace landscape.



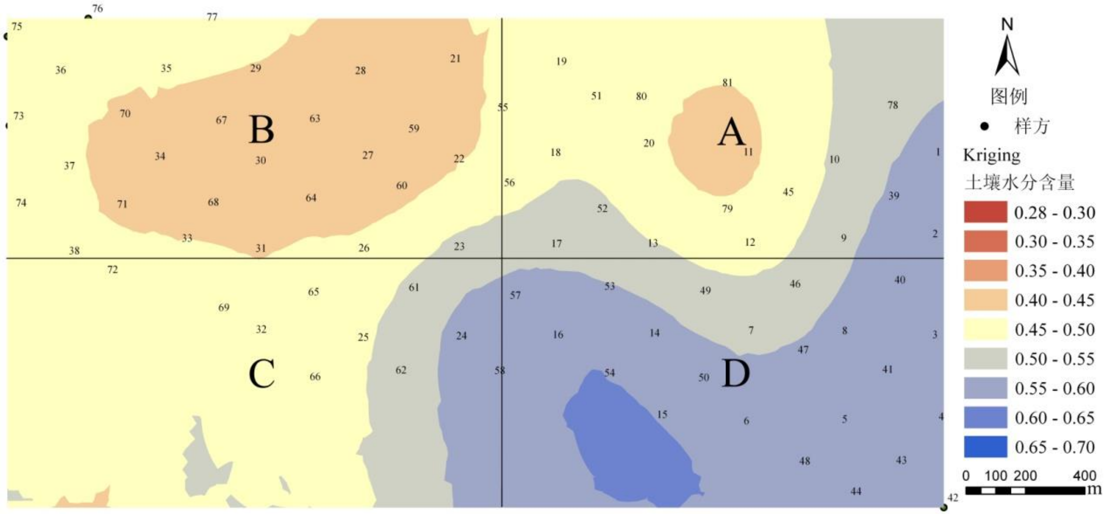


Figure 20. Spatial distribution of soil moisture content in the dry and rainy season

3.8 The role of vegetation in hydrological function of Honghe Hani rice terraces

Based on the investigation of vegetation, analysis of landscape pattern and watershed hydrological unit in the plots of Quanfuzhuang river basin, we selected five vegetation types (totally 7 sample plots): grassland I and II, original forest III, sub-original forest IV, artificial forest V, tea-garden land IV and farmland VII, analyzed the water conservation function of various vegetation types via soil, litter and canopy layer. The results indicated:

Soil is the most important body for water conservation, the soil water capacity is a reflection of the importance indicators of water conservation. (1)The order of the maximum water capacity of the surface soil (0-60cm) is: original forest III, grassland I, sub-original forest IV, artificial forest V, tea garden land VI, grassland II and farmland VII. (2)The order of soil permeability is as follow: forest land, grassland and farmland. (3)The order of steady-state hydraulic conductivity is tea garden land VI, sub-original forest IV, original forest III, grassland I, grassland II, artificial forest V and farmland VII. (4)The biomass order of different kinds of vegetation types is: original forest III, sub-original forest IV, grassland I, grassland II, artificial forest V. (5) During the period of 2014.7 to 2014.9, 39 times rainfall were observed in three different types of forest plots (original forest III, sub-original forest IV, artificial forest V). The results suggested that the amount of canopy interception is increased with the amount of rainfall. (6) Average canopy interception of sub-original forest IV is 39.47%, and original forest III is 34.43%, and artificial forest V is 27.89%.

3.9 The water distribution in the rice terraces

Water is one of the vital natural resources for the rice plantation. The stability of water supply is the key to the sustainability of the Cultural Landscape of Honghe Hani Terraces. We take Quanfuzhuang River basin which is located in the core area of the heritage as the object, obtain the spatial distribution and structural characteristics of rivers and ditches based on QuickBird image and field survey. We select the slope and the distances from rivers and ditches as the two resistant factors, analyze the connectivity of river-ditches based on the least-cost distance model in ARCGIS. The result indicate:

(1) The irrigation resistance of the Hani Terraces by rivers and ditches are higher than by river-ditches network. It is seen that 69.5% area of total terrace can get stable irrigating water by river-ditches network.

(2) Taking the self-irrigation and two-way irrigation terraces into account, the stable area of irrigation water of the Dayutang village is increased from 80% to 81.6%, while the Xiaozhai village is increased from 86.1% to 86.6%, which indicate the higher stability of irrigation water of Hani Terraces.

3.10 Water Security in Hani Terraces

Introduction

In the Hani terraces, instances of water scarcity and periods of concentrated availability have been noticed, both in the upstream and the downstream reaches, under historical and future rainfall scenarios. Reconciling water availability with equitable access has been identified as the most important issue that needs policy formulation and institutional arrangements. Integrated water management is proposed as the central theme for sustainable development of the region keeping intact its rich cultural heritage and the unique rice production landscape. We use water scarcity index as a tool to identify and understand threats to water security and is found to be an appropriate way of looking at overall changes in demand and supply. The analysis is conducted with available spatial data derived from satellite and global data sets complimented with field surveys, and estimates are expected to be representative. It is seen that the water scarcity index can also be used to identify periods in which action is required and show if interventions can really help solve a given problem in an acceptable manner for all stakeholders.

Methodology

Water security is defined as the "Capacity of a population to safeguard **sustainable access** to **adequate quantities** of acceptable quality water for **sustaining livelihoods, human well-being, and socio-economic development**, for ensuring protection against water-borne pollution and water-related disasters, and for **preserving ecosystems in a climate of peace and political stability**" United Nations University-INWEH (2013)

In this research we use the spatially distributed water scarcity index, which is used to express the balance between the potential water availability and the current water demand as an indicator of the water security. Temporal and spatial variation to the index can be used to observe the changes to the water security and measures to be adopted for the regions concerned under present or future projected scenarios. The index is defined as,

$R_{ws} = (W-S)/Q$

Where W: annual total water withdrawal, S: desalinated water and Q: annual available water resources. Often in a region such as the study area, observations of actual water withdrawals are not available and some components have to be estimated from water demand and observed withdrawals, in lieu of actual water withdrawals.

The interpretation of water scarcity index is given in the Table 2

Table 2. Water scarcity and its interpretation

Range of values	Interpretation
Rws < 0.1	No stress
0.1 < Rws < 0.2	Low stress
0.2 < Rws < 0.4	Moderate stress
Rws > 0.4	High stress

The estimation of the Rws is carried as per the flowchart shown in the Figure21. The research objectives 1 and 2 shown in the figure are defined as,

Research Objective 1: Analysis of water availability- surface runoff and subsurface water availability estimation for the upstream and downstream watersheds. Obtaining future rainfall values under RCP 2.6 and 8.5 and analysis of water availability under RCP 8.5

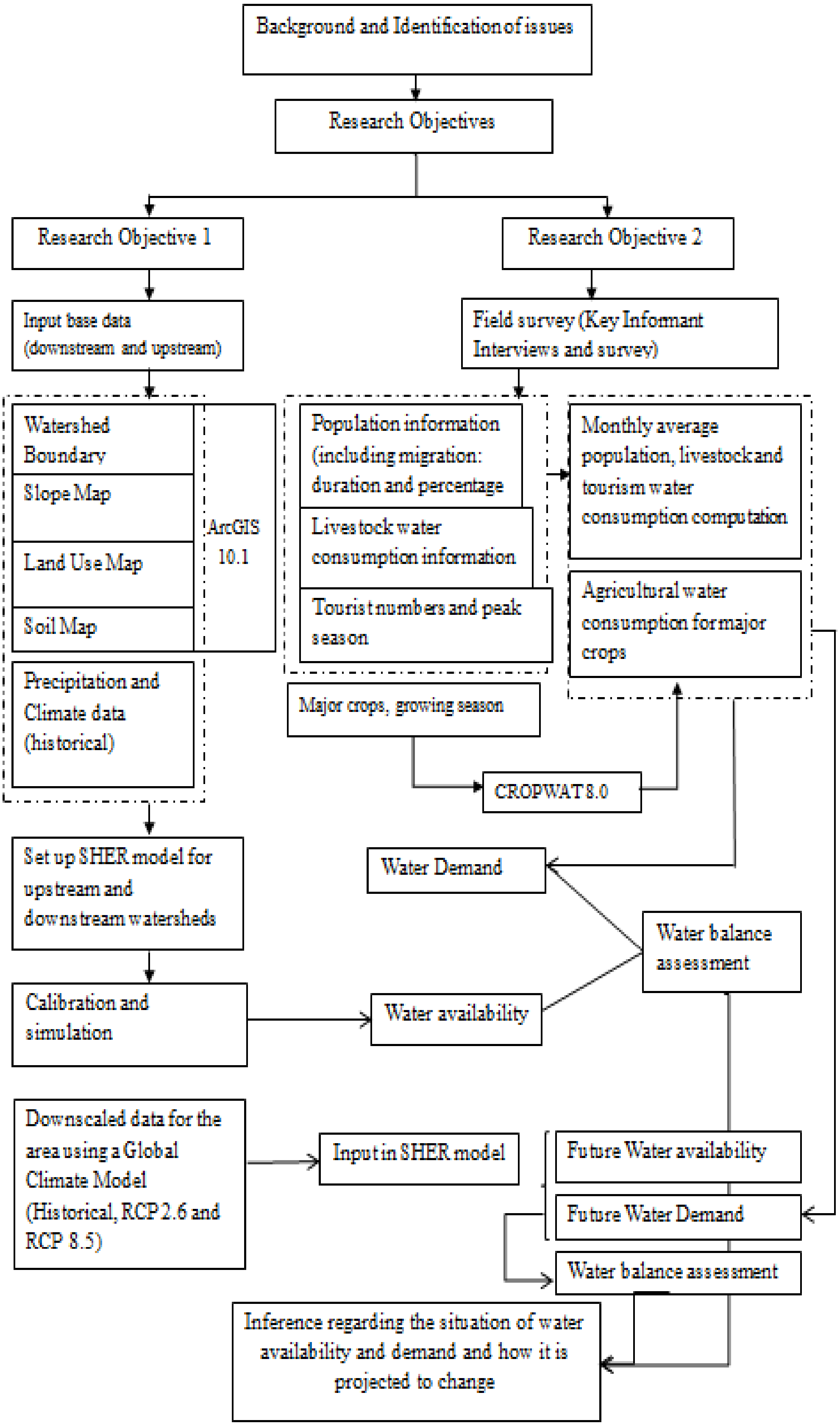


Figure 21. The methodology adopted in computing Rws

Research Objective 2: Analysis of water demand for the major water use sectors that are considered: domestic (including consumption for washing, cooking, other miscellaneous household purposes and for livestock), agricultural water demand and tourist water needs (only specific to the upstream reaches) in the upstream and downstream watershed.

The Similar Hydrologic Element Response (SHER) model was used to assess the water availability in the upstream and downstream watersheds using precipitation data obtained from the Asian Precipitation Highly Resolved Observation Data Integration Towards Evaluation or APHRODITE database for 1998-2007.

Calculation of water demand was done considering four major demand sectors, domestic, agriculture, livestock and tourism (specific to upstream watershed). Details regarding population numbers, migration patterns, growing seasons for major crops and livestock information were collected from the field using Key Informant Interviews with the village leaders (5) and guided questionnaire surveys from farmers (9 upstream and 8 downstream) and restaurant owners (4 upstream) and water demand was calculated using national average per capita water consumption figure of 86 lpd (United Nations Development Programme, 2006) and extrapolated to the populated portion of the built up area of the watershed.

Study area

Field visits to the rice terraces showed that this area faced threats associated with access to water, and disparities existed within the different reaches and between the protected area and the other parts of the system further downstream. In order to assess the differences among the villages we selected 3 upstream villages and 2 downstream villages in the region. Their locations are given in Table 3.

Table 3: Selected villages with location coordinates

Name of Village	Location	Altitude
Quanfuzhuang	102.76 E, 23.11 N	1833
Dayutang	102.74 E, 23.10 N	1830
QingKou	102.74 E, 23.12 N	1671
Downstream reaches		
Anfenzhai (dazhai) or Anfenzhai big village	102.76 E, 23.17 N	1340
Feimo	102.77 E, 23.20 N	1263

Temporal and spatial distribution of Water Scarcity Index

Considering the water distribution schematic of the area, in the upstream reaches, water from artificial private owned storage ponds are utilized to supplement the flow from the mountains during the dry season. These ponds were represented in the basin hydrological model as storage detention ponds with a capacity of 240 m^3, which discharges during the 70th to 150th days of the year i.e. mid-March to mid-May. The resultant water availability shows a fairly distributed peak. The groundwater head is sensitive to the changes in the water availability, showing that the contribution of groundwater in this system is important and significant.

While the four upstream villages are contained in one watershed, the two downstream villages are located in two different watersheds requiring the setup of 3 catchment models for the analysis. The characteristics of the villages are summarised in the Table 4.

Table 4: Characteristics of the villages studied in 2015

Upstream reaches

Name of village	Population	Average field (Mu)[1]	Major crops	Growing season	Water sources	
					Domestic Use	Terrace
Quanfuzhang	2,500	3	Rice; Corn; Pea	Sowing and Transplanting: Mar-May Harvest : Sep-Oct Field Preparation : Nov-Jan	Spring water collected in storage tanks	Surface runoff channeled through a canal and ditch system
Dayutang	350	2	Rice; Corn			
QingKou	1115	3.5	Rice			

Downstream reaches

Name of village	Population	Average field size(Mu)	Major crops	Water sources	
				Domestic Use	Terrace
Anfenzhai (dazhai)	385	2	Maize/Corn; Rice	Spring water collected in cisterns, piped water supply	Rainwater
Feimo	570	3	Sugarcane; Corn; Alfalfa	Piped water supply from a nearby spring	

1 Mu is one of the Chinese units of area. 1 Mu= 666.7 m^2

For the future scenarios, downscaled rainfall data was obtained from the CORDEX database (EC Earth model) for 2030-2040 for RCP 8.5 scenario, checked and corrected for bias and used as the input rainfall in the model to estimate available water resources. Water demand was modified by assuming that per capita water consumption will increase in the future to 100 LPD. The current and future changes to water scarcity index for the upstream villages are shown in Figure 22. The corresponding variation for the downstream areas is shown in Figure 23.

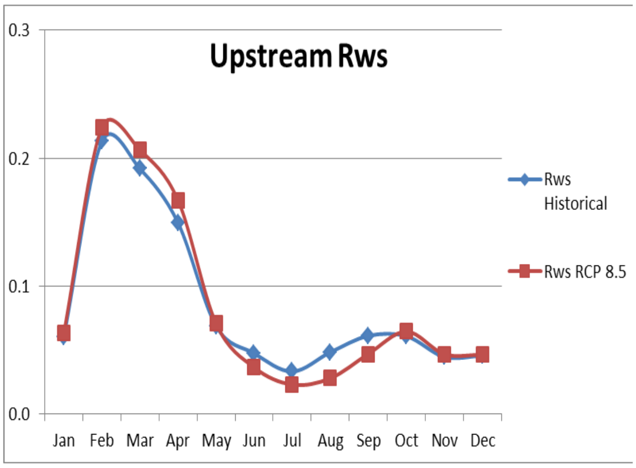


Figure 22 Variation of water scarcity index in the upstream reaches

The comparison of water scarcity index values point towards the fact that wet and dry periods are set to become more pronounced, even more so in the downstream watershed as can be seen from Figures 22 and 23.

Proposal for Physical measures

In the upstream watersheds, the effect of interventions was explored, by considering expansion of water retention ponds. An example of such ponds is shown in Figure 24. They are privately owned water resource areas used during dry periods or when there is a need for additional water such as transplanting or repairing fields or bunds. We considered the effect of doubling the number of the storage provided by these ponds upstream. The resulting shift of Rws compared to the Rws under business as usual for 2030-2040 is shown in Figure 35. It is seen that such structural measures can be implemented with relative ease to increase the water security under future climate change scenarios.

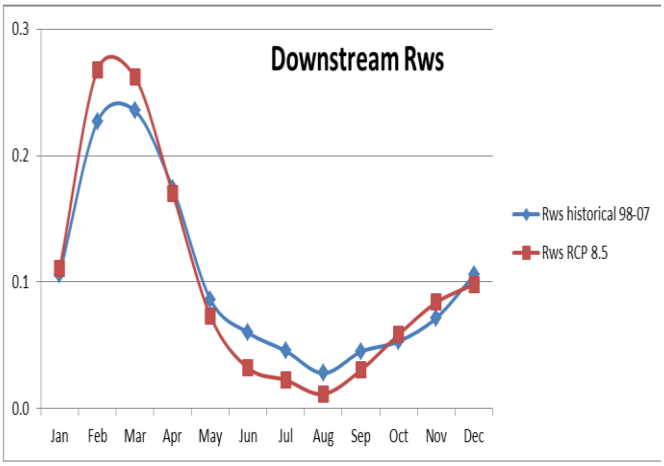


Figure 23 Variation of water scarcity index in the upstream reaches

Figure 24. Example of water retention ponds in the headwaters of Hani terraces

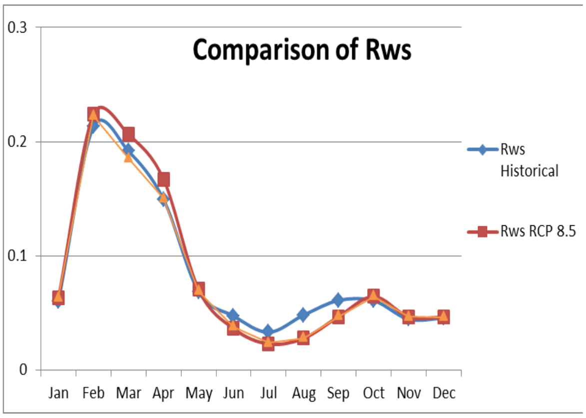


Figure 25 Variation of water scarcity index in the upstream reaches after doubling the storage capacity of upstream ponds, shown by orange colour line.

Proposal for Institutional arrangements

During the field visits we have seen acute water scarcity in some of the downstream villages. This status is more than one would expect from the Water Scarcity Index Rws. This means that while the resources are available access to those resources is much more difficult, or is not facilitated, as expected in the average ranges usually employed in the assessment of water scarcity. This is especially true for the downstream villages. According to the respondents, the traditional water management systems, which involved ditch leaders for water allocation and the use of carved wood locks for distributing water, amongst different systems, were no longer in practice. Instead, most upstream respondents stressed that farmers themselves were in charge of the water resources in their area and allocation and dispute redress was done through negotiations. A farmer from QingKou mentioned that the allocation depends on “the size of the field. The bigger the land size, the priority is given for receiving water and also the quantity received, followed by the smaller lands. Stones are used to control the flow in this case”. In contrast to this, the downstream areas depended mostly on the Government agencies and the water supply company for supply and management. Most villages pay for piped water supply, and as mentioned before, the villagers from Feimo had to pay to get water from a spring allocated to them after they approached the Government following a long battle with water scarcity. In the upstream reaches too, piped water supply was made available to meet additional demands, again supplied by the water supply company (called Zilaishui in the local language). A significant outcome of this was the loss of the traditional water distribution system, which was perhaps responsible for maintaining the delicate balance of the system. The approaches taken to ensure access to water are scattered and seemingly temporary, but it is interesting to see how the management approach has become more top-down and involving figures of authority in the areas downstream where the shortage of water is being felt more. At the same time, the more decentralised management being followed in the upstream areas does not seem to incorporate cooperation between other villages in the surrounding area.

It is clear that the terrace system has challenges that are unique, and sustenance of the system needs an integrated strategy. Looking at the macro perspective, management ideas can be sourced from policy instruments like the national laws. The national water law elucidates that a river basin needs to be considered as the basic unit for the formulation water allocation strategies. In this case, the presence of a basin level strategy would ideally allow officials from departments responsible for the administration of the area to make informed decisions along with the officials responsible for the maintenance of the systems that contribute to the cultural heritage of the site, like the water system. The establishment of a nodal authority would reduce the discrepancies in decision making brought about by overlapping responsibilities and rights in the area. It would allow for collective decision making on issues while allowing comprehensive problem solving and providing a direct common platform for doing so. Possible re-introduction of traditional systems is a one such measure, which needs to be looked into. Addressing issues like groundwater rights and abstraction along with headwater rights can be made easier through this approach as the authorities would have a comprehensive understanding of the system as a whole, which could aid in making informed decisions.

The more micro scale challenges can be resolved by utilising platforms for greater engagement among the farmers themselves. Some of the systems, which exist in other parts of the country that could be replicated here include setting up of Water User Associations or WUAs, like the ones existing in northern parts of China (Huang et al., 2010) or the establishment and utilisation of farmers cooperatives under the provisions of the Cooperative Law (Tang et al., 2015). These platforms could gather and disseminate information related to status of water use and availability along with monitoring and local management. This will be used to inform public opinion and influence decision-making across the different reaches of the terrace system.

4. Conclusions

Restate the study aims or key questions and summarize your findings

Overall findings

- The climate change will impact the stability of rice terrace system, increasing the frequency of the landslide numbers in the Ifugao Terraces in the Philippines and aggravating the water scarcity in Hani terraces, China. However, the extents of these increases are not catastrophic and manageable by enhancing existing adaptive capacities.
- It is important to address other pressing issues, such as livelihood improvement, migration and benefit sharing in a holistic manner with climate change to ensure the sustainability of the rice terrace systems.
- The past experience shows, solutions, even though designed to improve economic and livelihoods, if not integrated to the functionality of the system, may lead to the disruption and abandonment of the unique features of the systems.
- It is a challenge to find overarching development themes that can improve the livelihoods while maintaining the beautiful landscapes that have been developed over thousands of years.

This research has contributed to the quantification of threats and identifying directions towards some such solutions.

Hani Rice Terraces

Key findings: Environmental threats and focus areas:

- It is seen that groundwater is a critical component of the water system in the area and its interplay with the surface flow and storage determines the water availability.
- The river-ditches network in the upstream areas provides stable irrigation water.
- There is an issue of water scarcity during certain periods in the upstream areas, which has been identified through analysis and verified through surveys with the people. The effect of scarcity is being felt more in the downstream reaches of the system.
- Climate change is set to impact the water availability, with dry and wet seasons set to become more pronounced.
- The water scarcity index is useful in showcasing the system threats and determining the timing and effect of on-ground interventions to aid effective decision making.
- Social threats and focus areas:
- Migration is an issue in the upstream and downstream areas. The traditional knowledge and the use of traditional resource management systems in the area have also been on the decline. This is a vicious cycle and it is affecting the sustainability of the terraces.
- The boom in tourism in the upstream reaches has impacted the communities significantly. On the one hand it has generated livelihoods and income for the people but the benefits have not been uniformly distributed, due to the lack of community involvement in the planning and decision making process. In some cases the sensibilities of the traditional practices has been affected.

Policy and Management threats and focus areas:

- The water management approaches are particular to each part of the system. Most upstream villages utilize negotiations and allocation practices, while the downstream areas depend on the Government agencies and the water supply companies. Traditional distribution and management practices are no longer followed.
- The policy provisions identified through the National Water Law and the Environment Protection Law do not adequately address the issue of groundwater abstraction and licensing, which is important in lieu of payments being made to utilize spring water in the downstream areas, along with the groundwater drawdown effects due to mining further downstream.
- Rights to water appear to be overlapping, especially in the headwater reaches in the upstream area, which is acting as the source of piped water supply for the surrounding villages and other towns in some cases.

Key recommendations:

- Accurate depiction of the impacts of system changes on the environment requires improved estimates of water availability, especially groundwater and 'depletion' or consumption made by analyzing the water system using detailed local field data. Utilizing tools like the Water Scarcity Index can be very useful to understand the environmental threats faced by the system.

- Measures to improve access to adequate amount of water need to be incorporated into the planning process, including possible structural interventions to increase storage, to withstand water scarce periods.
- These measures require strengthening of the institutional arrangements contributing to the development of the area. A platform for collective decision making could aid in this, which is why the development of a holistic, basin level strategy should be undertaken. Establishment of a nodal authority for improving inter-agency coordination along with development of local platforms for engaging, involving and consulting local stakeholders has to be done.

Ifugao Rice Terraces

<u>Key findings</u>

- The Ifugao rice terraces (IRT) and its communities face a two-pronged challenge: economic inadequacies and erosion of cultural heritage. To achieve sustainable development of these agricultural heritage systems, a holistic integrated approach is necessary to address all aspects of the problem.
- This calls for policies advancing benefit-sharing mechanisms to produce incentives that would help address both the challenges of providing sustainable livelihood to the communities while conserving their natural environment and cultural heritage. Measures that allow obtaining comparable income to those opportunities in lowlands will help make farming in rice terraces more promising. There are several opportunities that call for the government to revisit its past policies and redirect efforts that could lead to more efficient and lasting results toward sustainable development of the rice terraces and its communities.

<u>Key Recommendations</u>

- A holistic approach should look at the sustainability of the IRT as a complete living system of people, environment and customary practices, consisting both of tangible and intangible elements.
- <u>*Carbon stock payment schemes*</u> (forest management policy) Results of the UNU-IAS study in the Ifugao *muyong* show that *muyong* forests have the highest carbon stocks among different carbon pools of the local forests (Herath, et. al., 2015). Carbon credit payment schemes under the UN-REDD+ (Reducing Emissions from Deforestation and Forest Degradation) programme where muyong owners and growers can receive payment from the government can be devised to discourage the owners from converting forest land to alternative uses. Whether the level of payment are land-based or tree-based, carbon payment schemes provide incentives to alter the behavior of the owners towards maintaining their forests. The forest management scheme should also consider water storage for extreme events triggered landslide increase that was identified in the landslide risk modelling of the system.
- <u>*Sustainable eco-tourism*</u> (livelihood sector) Parties to the Convention on Biodiversity (CDB) adopted guidelines involving indigenous peoples and local communities in tourism development and many governments have embraces the potential of tourism through actively promoting ecotourism development. The local NGO, Save the Ifugao Terraces Movement (SITMo) has successfully implemented culture-sensitive tourism through community involvement. This can also

expand to mass tourism, learning from the experiences of Hani rice terraces in China that are packed with local tourists who bring diverse business opportunities to the terrace region. A learning alliance with the Hani Rice Terraces is highly recommended to support expansion in to this area.

- *Environmental services payments* (benefit sharing) IRTs function as watershed, supplying water to and serving several dams such as Ambuklao Dam, Binga Dam, Magat Dam, and San Roque dam for neighbouring regions and even parts of the Metro Manila through maintenance of the highland forests like the *muyong*. Collectively, the province supports about 945 MW in these hydroelectric dams, which is about 60% of the waters that are electrifying Luzon. During the public forums and policy dialogues many local participants expressed that there should be some benefit sharing mechanism where the headwater people as custodians of watersheds to receive some of the benefits derived from this water. It may be worthwhile to investigate the feasibility of taxing water based revenues and transfer of some to upstream region for infrastructure development and other subsidies.

5. Future Directions

Implementing the recommendations identified in the study is an important aspect of future work.

a. Identifying some potential entry points for each strategy is crucial in ensuring that policies are relevant and effective in addressing the impacts of changing climate to the rice terraces. For this end, it is proposed that (a) academics are nominated to the policy making bodies of climate change and indigenous affairs and (b) start up some incubator projects incorporating all stake holders that can develop into large scale development practices. The UNU-IAS frame work INATE (International Network for Advancing Transdisciplinary Education) is a framework that can be used to implement such projects.
b. Through technology and sustainable practices, optimization of weather forecasting and modeling though inter-agency cooperation should be made compatible to traditional practices of the local communities. Scientific understanding of the farmers should be enhanced through capacity building programs.
c. Through policies, payment for environmental services such as water user's fee based on equal sharing with upstream and downstream communities can be implemented. Attractive incentives to the Ifugao people who maintain the rice terrace systems can be offered through economic interventions such as alternative livelihood programs.
d. Climate change profiling and building up common indicators for planning implementation and monitoring purposes both in local and national level should be established. Information management system and data sharing making data accessible will enable better forecasting and strategy design by participating agencies for climate change adaptation.

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Appendix

Activity Report

PROJECT:"DEVELOPING ECOSYSTEMS-BASED ADAPTATION STRATEGIES FOR ENHANCING RESILIENCE OF RICE TERRACE FARMING SYSTEMS TO CLIMATE CHANGE"

LOCATION: **Manila and Ifugao Province, Philippines**

DATE: **26 to 30 July 2015**

I. Introduction

UNU-IAS and Yunnan Normal University project members conducted a field visit and two concluding fora at Ifugao Province and Manila, Philippines. The following were present during the said activities:

Dr. Srikantha Herath, UNU-IAS (Project Leader)
Johanna Diwa, UNU-IAS
Mario Soriano, UNU-IAS
Luohui Liang, UNU-IAS
Dr. Yuanmei Jiao, Yunnan Normal University

They were joined by Engr. Loinaz Dulawan of Ifugao State University.

II. Activities Undertaken

Ms. Diwa arrived in Manila on 23 July to start the preparations for the trip and the events, while the rest of the team arrived on 25 July. On the morning of 26 July, the team conducted an initial meeting at Hotel Jen Manila, where they were checked in. They then took a road trip and proceeded to Ibulao in Ifugao Province, which served as their accommodation for their entire stay in Ifugao.

Figure 1. a.) One of main lodges at Ibulao; b.) the project team members at Ibulao

The following morning, July 27, the team was visited by Ifugao State University (IfSU) President Dr. Serafin Ngohayon and Vice President Dr. Napoleon Taguiling. Dr. Herath discussed with them the objectives and details of the trip and also thanked IfSU for their partnership in organizing the events related to the project for the last 3 years.

Figure 2. The project team with IfSU's Dr. Napoleon Taguiling and Dr. Serafin Ngohayon

After that brief visit, the project members proceeded to a courtesy call to the office of Hon. Denis Habawel, Governor of Ifugao. The team discussed the outcomes of the project, and the governor gave his feedback on what he sees as some key concerns for the rice terraces. He also shared his government's initiatives to draft a Sustainable Tourism Master Plan in accordance with UNESCO guidelines, which included inviting experts from all over the world to provide inputs for the plan. It was learned that Dr. Jiao recently helped in preparing such plan for the Hani Rice Terraces. The governor expressed great enthusiasm in learning from the experience of the Hani Rice Terraces in order to ensure the success of the efforts to draft an equivalent plan for the Ifugao Rice Terraces.

In the afternoon, the team convened for an Experts Workshop where they presented updates in each working site, including the final findings that they will be presenting to the local stakeholders in Ifugao in the IfSU workshop on 28 July. The team also discussed further steps in the remaining period for closing the project as well as publication and further direction afterwards.

Figure 3. The project team meets with Hon. Governor Denis Habawel

The next day, July 28, the team conducted a field visit to the Open Air Museum of the Nagacadan Terrace Cluster in Kiangan, one of the five terrace clusters in Ifugao listed as a UNESCO World Heritage Site. During the site visit, the team was able to interview some local farmers. They also visited the catchment where the automated rain gauge and Parshall flume were installed.

Figure 4. Rice crops nearing harvest at the Nagacadan Terrace Cluster in Kiangan, Ifugao Province

Figure 5. The project team's field visit at the Nagacadan Terrace Cluster, Kiangan, Ifugao Province

After the field visit, the team conducted a forum which was organized by partner university IfSU, entitled “International Forum on Current Global Challenges and its Relevance to the Ifugao Rice Terraces System.” The said forum was held at IfSU’s Lamut campus. It was attended by IfSU faculty and students, and local stakeholders such as rice terrace farmers, local government representatives, and other researchers.

Figure 6. The resource speakers at the IfSU Forum: Dr. Ngohayon, Mr. Martin, Prof. Liang, and Dr. Herath

During the forum, IfSU Pres. Dr. Ngohayon talked about the current global challenges of the Ifugao Rice Terraces, and the role of the Ifugao State University. He shared some focal programmes of the university in strengthening the passing on of knowledge systems through meticulous documentation of indigenous beliefs and practices, and emphasized the need for continuous capacity-building of the locals. Dr. Ngohayon generously gave copies of IfSU’s latest publications to Dr. Herath, Dr. Jiao, and Prof. Liang as a token of gratitude.

Mr. Marlon Martin, chief operating officer of Save the Ifugao Terraces Movement (SITMo), delivered a talk on the current initiatives of his organization in addressing the challenges to the rice terraces. He also focused on capacity-building efforts, and urged the audience to ponder their definition of what development should be. He also stressed the need for inclusive development, not only in the UNESCO-inscribed rice terrace clusters, but also in those areas outside the World Heritage Sites. Furthermore, Mr. Martin shared current developments in his organization’s research collaboration with Dr. Stephen Acabado, Professor at University of California- Los Angeles, on determining the true age of the rice terraces. Their findings suggest that contrary to the popular notion that the rice terraces are 2,000 years old, excavations show that they are only around 400 years old. Their work provides valuable insights into the actual development phases of the Ifugao rice terraces. Dr. Acabado was also present in the forum.

Prof. Liang discussed the experience of the Hani Rice Terraces, along with the indigenous agrodiversity practices which enhance the resilience of this system to droughts and other climate stresses. He talked about the use of storage ponds, the importance of water throughout the year, and the presence of preserved forest areas. He also talked about the sudden boom in tourism since the area was recognized as a World Heritage Site in 2013. He also pointed out the opportunity for Hani to learn from the experience of Ifugao, which has been in the heritage list since 1995.

Dr. Herath then gave a presentation on the advances in research on the sustainability of rice terrace systems, and discussed how these results could aid in better management of the rice terraces. He presented a weather prediction model which was based on downscaled global circulation models, and showed how it successfully predicted rainfall to start occurring at 15:00 hours that day. He also talked about the potential increase of storage ponds as an adaptation measure for projected climate change in the Hani Rice Terraces to address possible water scarcity. Dr. Herath also mentioned how the slope stability of a study catchment in Bayninan, Kiangan was minimally perturbed by fluctuations in extreme rainfall based on simulations for September of the previous year. This suggested that the rice terraces are possibly resilient to slope failure due to increased pore water pressure. He also emphasized the need to increase scientific observations and data collection to improve the results of these models. Finally, Dr. Herath presented an opportunity for the Ifugao Rice Terraces to benefit from climate change. A recent UNU-IAS study showed that the indigenous *muyong* forest management system had greater carbon storage compared to other forest types, suggesting that this practice might potentially benefit from the UN-REDD+ scheme.

The floor was opened for a discussion session after the presentations. One of the most brought up concept was the need for a scheme for downstream communities to transfer the benefits they get to the Ifugao province, which is upstream. This was framed as a form of payment for ecosystem services by Prof. Liang. It was asked whether it was possible to quantify the water yield for every single tree in the *muyong* so as to come up with a clear tariff system for maintaining the forests. Dr. Herath responded that such an endeavour would be very difficult to prove, especially considering that the so-called water yield varies depending not only on the tree species, but also on the characteristics of the rainfall event, and the antecedent soil moisture conditions. However, he provided several successful upstream-downstream agreements between communities in Japan, which did not require going very specific into the level of accounting for the contribution of every single tree. Other points of discussion include hydropower and proposed dam developments in the province, strengthening the cultural identity and pride of young Ifugaos, and learning how the Chinese government managed to rapidly develop tourism in the Hani Rice Terraces.

The open discussion was followed by a response from the government, delivered by Ms. Mariflor Dipia-o Capuyan of the Ifugao Cultural Heritage Office (ICHO). She enumerated several government initiatives under the ICHO to try to address some of the concerns brought up in the forum, and expressed her gratitude for the research efforts and outcomes of the project. The event was formally closed by IfSU Vice President Dr. Taguiling. A dinner reception hosted by IfSU President Ngohayon followed the forum.

Figure 7. Highlights from the open discussion

Figure 8. (L to R) Ms. Mariflor Dipia-o Capuyan (Ifugao Cultural Heritage Office), Ms. Diwa, Dr. Jiao, Prof. Liang, Mr. Jose Cabrera Jr. (Lamut City Environment and Natural Resources Office/ CENRO), Mr. Martin, Dr. Herath, Dr. Ngohayon, Dr. Taguiling, Dr. Acabado, and Engr. Dulawan

The project team members returned to Hotel Jen Manila on July 29.

On July 30, the team conducted a science-policy forum entitled "The Sustainability of the Rice Terrace Systems (Hani and Ifugao): Building Learning Alliance" at the Embassy Ballroom A of Hotel Jen Manila. The forum was attended by various representatives from the academe, government, environment-related non-governmental organizations, and the private sector. Notable attendees include the presidents of the state universities and colleges in the Cordillera Administrative Region, representatives from the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA), Department of Science and Technology (DOST), Haribon Foundation, Toshiba and higher education institutions and universities. This science-policy forum was partly co-organized by IfSU and the University of the Philippines. Ms. Diwa served as the Master of Ceremonies.

Figure 9. a.) The venue of the science-policy forum; b.) The working papers for the project

Dr. Herath delivered the opening remarks, where he emphasized the relevance of traditional rice terrace systems to sustainability and resilience, and the need to address the current global challenges which they face. He also spoke on the possibility of greater collaboration and learning from the common experiences among the many rice terrace systems in Asia, with Ifugao and Hani, two UNESCO World Heritage Sites, being the leaders in this learning alliance.

Dr. Jiao's presentation focused on the challenges and advances to enhancing the resilience and sustainability of the Hani Rice Terraces. She introduced the integrated farming system in Hani, which consisted of four inter-connected subsystems: mixed agroforestry, cultivation and breeding, economic subsystem, and social and cultural subsystem at the center of the web. She also enumerated several challenges to Hani, as well as some of the project activities undertaken to help address these problems. Dr. Jiao also discussed the resilience mechanisms of the Hani Rice Terraces, and explained some traditional ecological knowledge of landscape elements management. At the end of her talk, she presented some possibilities for future research, which include hydrological, economic, and socio-cultural themes on how to promote the maintenance and ensure the sustainability of the Hani Rice Terraces.

Hon. Loren Legarda, Senator of the Republic of the Philippines, delivered the keynote address for the event. She talked about her recent collaboration with the state universities and colleges in the Cordillera Administrative Region, which resulted in a coffee-table book entitled "Guardians of the Forest, Stewards of the Land." She believes that documenting the indigenous practices of sustainability of the Cordillera people in all forms of media is an important undertaking. The senator also stated some climate change projection for the Ifugao province, which include increased rainfall intensities, a longer dry season, resulting in water shortages, landslides, and terrace collapse. She emphasized that the traditional knowledge and practices of the Ifugao and Hani people are the key to addressing the challenges of modern times. Sen. Legarda urged the panellists of the forum to share the outcomes with her, and said that she intends to use these findings for a privilege speech in the Senate, and possibly include it in the second volume of her book. The audience responded to her call with a resounding applause.

Figure 10. Senator Legarda delivers the keynote address

IfSU Pres. Dr. Serafin Ngohayon talked about the challenges and advances to the sustainability and resilience of the Ifugao Rice Terraces. His key discussion revolved around the initiatives undertaken to remove the Ifugao Rice Terraces from the World Heritage in Danger List in 2012. He shared some continuing challenges, such as the disturbed ecosystem, inadequate income of rice terrace farmers, deterioration of the rice terraces' cultural foundation, and inadequate support to rice terraces conservation. Lastly, he shared some advances in the restoration and conservation of the rice terraces through initiatives from IfSU, the local and provincial government, as well as national and international projects, including the Satoyama Meister Training Program with Kanazawa University, partnerships with Kobe Gakuin University and UNU, and the construction and operation of mini-hydro power plants through grants from JICA.

This talk was followed by Dr. Herath's discussion on the UNU-IAS comparative studies of the Hani and Ifugao Rice Terraces. He highlighted the need to address water scarcity in Hani, and the opportunity to enhance livelihoods in Ifugao through the UN-REDD+ program. He also emphasized the need for collaboration among researchers and the local communities to better improve the performance of climate models and weather forecasts, as well as to have a better understanding of the local mechanisms of groundwater movement and slope stability. He stated the need for regular communication with the user group, namely, the local farmers, to identify the type of scientific information that they need in order to better manage the terraces. Finally, Dr. Herath concluded by saying that climate change challenges provide an opportunity to pool resources, monitor, understand and model environmental processes that will help in reducing future risks and enhance optimal resource use.

Figure 11. (L to R): Ms. Diwa, Dr. Jiao, Dr. Herath, and Dr. Ngohayon at the science-policy forum in Manila

A panel discussion followed the presentations. The panel consisted of: Prof. Liang (UNU-IAS), Dr. Dixon Gevaña (University of the Philippines- Los Baños), Dr. Ngohayon (IfSU), and Dr. Jiao (Yunnan Normal University), and moderated by Dr. Guillermo Tabios III (University of the Philippines- Diliman). Each of the discussants raised points on possible interventions for the Ifugao and Hani Rice Terraces, including schemes for payment of ecosystem services, master planning for tourism and other activities, enhancing indigenous knowledge systems, promoting use of appropriate agricultural technology, and promoting cultural pride to encourage youth to continue their heritage. Some of the audience members raised questions and provided suggestions on collaborating with current ongoing initiatives and possible future projects for the Ifugao and Hani Rice Terraces. Prof. Peter Castro of UP Diliman formally delivered the closing remarks for the forum.

Figure 12. a.) The members of the panel discussion give their insights on the sustainability of the rice terraces; b.) Prof. Castro delivers the closing remarks

Below are some of the other highlights from the science-policy forum in Manila.