UNITED NATIONS UNIVERSITY
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Rice Terrace Farming Systems
Working Paper Series
Number 02 — June 2015

Ensuring Water Security for the sustainability of the Hani Rice Terraces, China against Climate and Land Use changes

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Rice Terrace Farming Systems
This working paper series share findings produced as part of the research activities under the Rice Terrace Systems in Rural Asia, a research project of the United Nations University Institute for the Advanced Study of Sustainability (UNU-IAS). The project aims 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 Hani Rice Terraces and Ifugao Rice Terraces.

To find out more, please visit **unu.edu/research/rice-terrace-farming-systems**

ABSTRACT

This study aims to assess the hydrological response of the selected study sites in the Hani Rice Terrace to climate change. Subsequently, it sets a process for analyzing a complex, interconnected hydrological system with varying topography and containing different landscape elements across different reaches for enhancing livelihoods of terrace communities. In the current analysis, instances of scarcity and periods of concentrated availability have been noticed, both in the upstream and the downstream reaches, under historical and future rainfall scenarios and demand changes. Reconciling water availability with equitable access has been identified as the most important issue that needs policy formulation and institutional arrangements. In this research, water scarcity index as a tool is used to idenity 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 a simple manner.

INTRODUCTION

Rice terraces are an important rice cultivation systems are well-suited for mountainous areas. As such, they are practiced widely in many parts of the Asia-Pacific. Mountain rice terraces have multiple benefits; they retain water within their walls and dikes made of compact soils and stones, conserve soil from erosion, create wet fields for intensive rice cultivation, and promote the sustainable development of mountain agriculture. For rural areas in general, rice terraces also play critical roles in shaping the landscape, and in soil and water conservation. The special ecological functions of rice terraces however are very much dependent on complex water management and are vulnerable to climate and envionmental change.

Recent studies show that climate change is expected to increase rainfall intensities and duration of droughts. While temperature forecasts show more or less consistent patterns in projections made by different Global Climate Change Models, the projections of future climate are very much subjected to assumptions made in the models related to physical processes, societal development trends, parameterization, model complexity, etc. Thus there is tremendous uncertainty in what the future climate could be. This is especially manifested in rainfall projections, which show large differences among the models. Such inconsistencies in rainfall projections make it difficult to make large investments in infrastructure such like large reservoirs and irrigation systems in rural areas for future water and food security. Furthermore, climate change-induced changes in the weather pattern will have serious implications for rice production. According to recent studies, increased temperatures in the tropics can lead to spikelet sterility and reduction in yields. For rural communities that rely on rice production, the most appropriate response under these uncertainties would be to focus more on “soft” measures in combination with existing infrastructure. Improved ecosystem management for water conservation is often a cost-effective way to enhance resilience to climate change. Therefore, the general aim of the wider objective of this research is to develop ecosystem based measures and address future uncertainty caused by climate change by enhancing the resilience of the rice terrace system and reduce the risks of climate change induced-floods and drought.

This paper presents a process set for analyzing a complex, interconnected hydrological system with varying topography and containing different landscape elements across different reaches for enhancing livelihoods of terrace communities. In the current analysis, instances of 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. In this research, water scarcity index as a tool is used to idenity 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 a simple manner.

Table 1: Name of 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

STUDY AREA

The rice terrace system located in the Yuanyang County of the Yunnan province in southwestern China includes the cultural landscape of the Honghe Hani Rice terraces, which was inscribed as a UNESCO world heritage site in 2013. A preliminary site visit to the area in 2014 showed that in addition to the issues mentioned above, the area also 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. Field surveys conducted using structured guided questionnaires also elicited responses related to observed scarcity. A respondent from the Quanfuzhuang village mentioned that "the months of March and April were the months in which they observed water scarcity in their village". Also, during the Key Informant Interview with the village leader of the Dayutang village, the respondent mentioned that the water levels are low during the months of February and March. Regarding management of water sources, there was evidence of co-management by the farmers themselves in the upstream watershed, while the downstream watershed saw a more top-down approach, with the villages depending on the Government agencies and water supply company for their water needs. In both cases, there were questions related to ownership and development of water resources, especially in the upstream areas, especially related to headwater ownership.
There was a need to comprehensively assess the water availability and demand balance in the area, under historical and future scenarios and understand how the issue of access to water could be addressed, from the management and structural standpoints, in light of the social threats faced by the area and by reviewing the existing policies and management practices. The concept of water security was utilized for relating the different components of the research, as it describes the capacity of a population to safeguard sustainable access to adequate quantities of water by preserving ecosystems in a climate of peace and political stability (United Nations University Institute for Water Environment and Health, 2013 pp1).

Yuan yang county is located between 22°49′N and 23°19′N and 102°27′E and 103°13′E, in the Yunnan province in south-western China (State Administration of Cultural Heritage of People's Republic of China 2013). The watersheds were delineated based on the selection of villages, three in the upstream reaches and two in the downstream reaches (see Table 1 and Figure 1). Landuse maps were created using Landsat 8 imagery for the area (Figure 2 and 3).

Figure 1: Upstream and downstream watersheds with the village locations

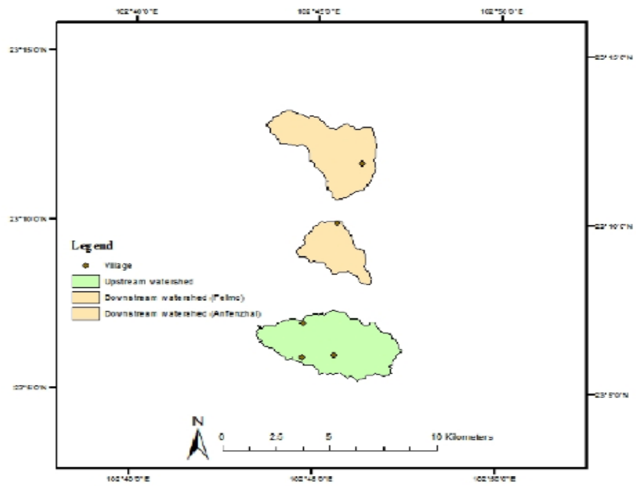


Figure 2: Land use map for the upstream watershed

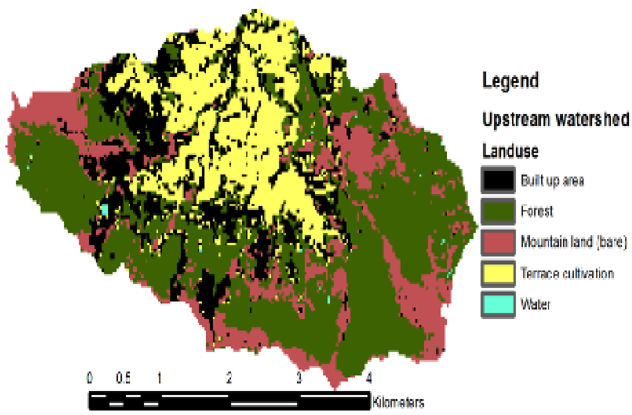
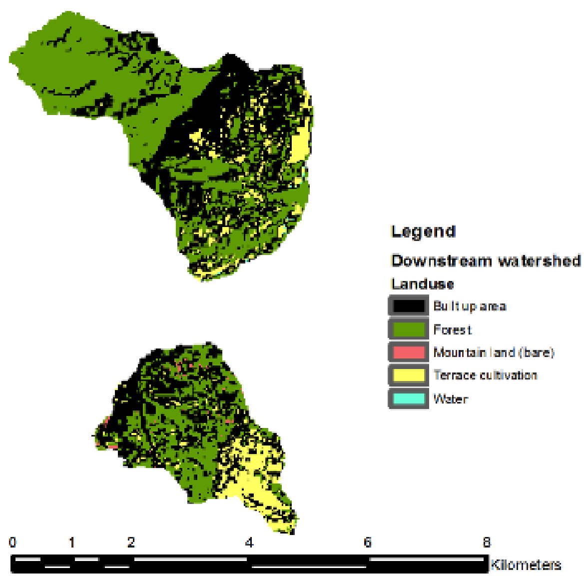


Figure 3: Land use map for the Anfenzhai and Feimo downstream watersheds



DATA COLLECTION AND RESULTS

WATER AVAILABILITY AND DEMAND ESTIMATION

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. The average monthly precipitation based on the data from 1998-2007 shows peak rainfalls from May to July, while rain decreases during February-April period.

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

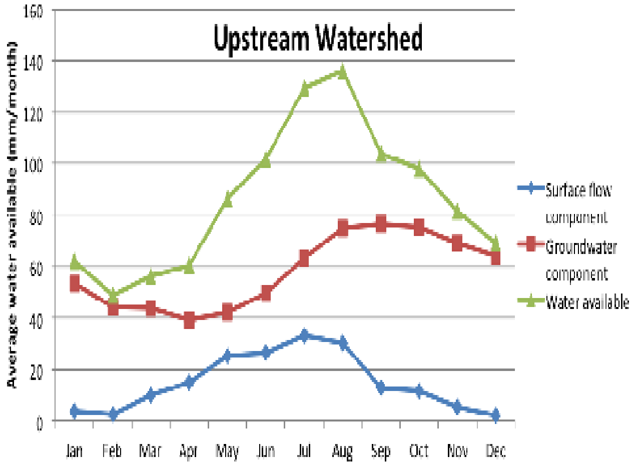
guided questionnaire surveys from farmers(9 upstream and 8 downstream) and restaurant owners(4 upstream) and water demand was calculated using national average per capita water consumption figure of 86 lpd (United Nations Development Programme, 2006) and extrapolated to the populated portion of the built up area of the watershed.

An important distinction has to be made regarding calculation of water demand v/s water consumption or depletion. In this research, water demand has been considered in terms of water 'use', i.e. the end water requirements by sector are taken as a proxy for the measure of water withdrawn from the source. However, according to literature, water balance estimations require the measure of water depletion or consumption, i.e. the use or removal of water from a basin which renders it unavailable for further use (Molden, 1997). It includes losses due to evaporation, flows to sinks, incorporation into the produce (like plants) and even pollution in some cases. Since there was no way of measuring the exact withdrawals from the source, especially as there were multiple water sources in the watershed itself, and in such a dynamic setup, the difficulties associated with measuring/estimating each invidual component resulted in the use of modified demand for the purpose of this research.

a. Upstream Watershed

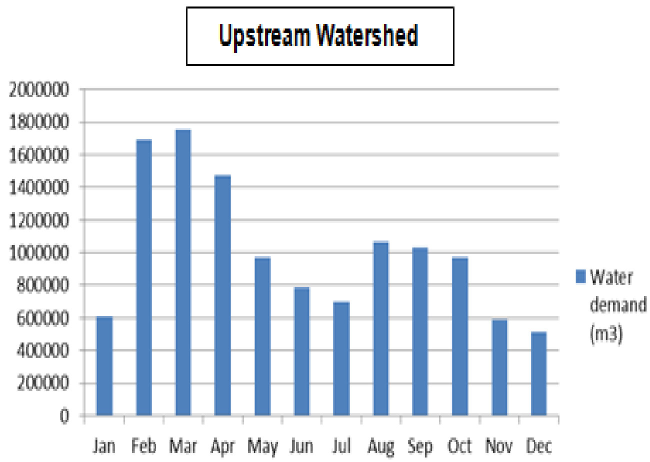
Considering the water distribution schematic of the area, in the upstream reaches, water from artificial private owned storage ponds are utilized to supplement the flow from the mountains during the dry season. These ponds were represented in the basin hydrological model as storage detention ponds with a capacity of 240 m3, 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. This can also be verified by looking at the contributions from surface and groundwater components towards the total water available (Figure 4).

Figure 4: Average per month contributions from surface flow and ground water flow towards the total water available in the upstream watershed (1998-2007)



For water demand estimation, domestic and livestock water requirements were calculated from the survey results . For agricultural water demand, Rice was considered as the major crop and the estimation was made using CROPWAT 8.0. Figure 5 shows the result of the overall demand calculation. It can be seen that February and March have the maximum demand due to the additional requirements generated from the tourism sector and the water needs for rice plantation, which increase the agricultural water needs.

Figure 5: Overall demand assessment for the upstream watershed per month, for 1998-2007



b. Downstream Watershed

Similar modelling was done for the downstream watershed, without considering supply from storage ponds. The peak was more pronounced in this scenario, with clear differences between dry and wet periods. The model results show a greater surface flow contribution during the wet season in this case, although the significance of groundwater component is reiterated (Figure 6). The demand analysis was also done, in this case water demand from tourism was not considered (Figure 7).

Figure 6: Average per month contributions from surface flow and ground water flow towards the total water available in the downstream watershed (1998-2007)

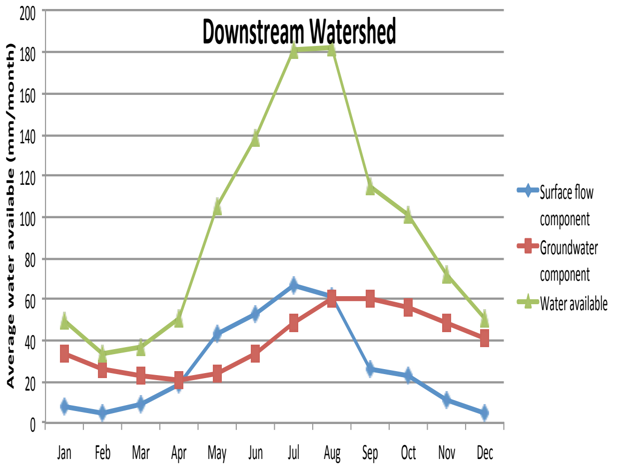
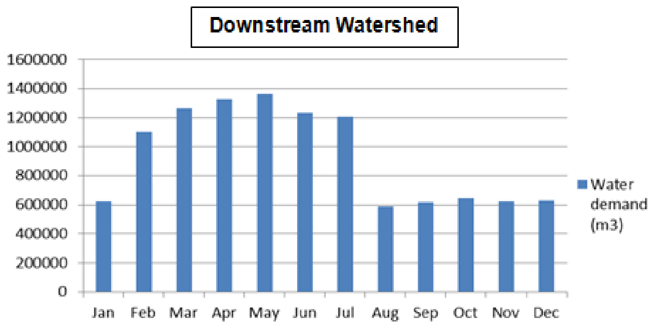


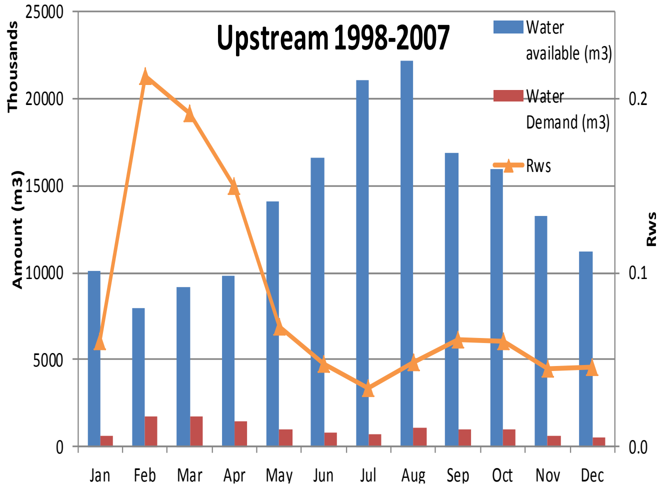
Figure 7: Overall demand assessment for the downstream watershed per month, for 1998-2007



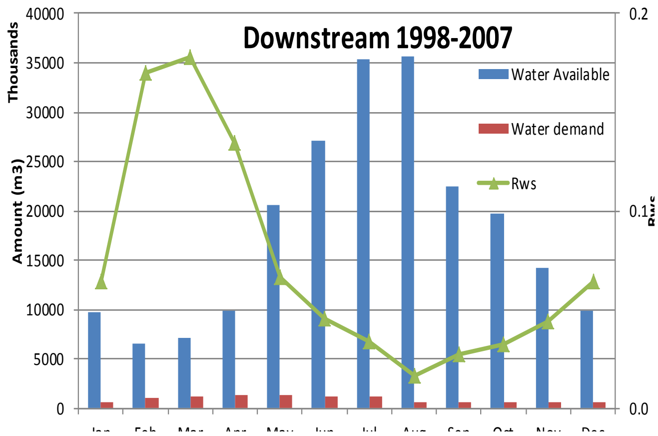
c. Water Scarcity Index

Water scarcity index (Rws) is given as the ratio of water withdrawals to the availability. The index values less than 0.1 indicate no scarcity, while values from 0.1-0.2 indicate moderate scarcity (Oki et al. 2001). In this study the withdrawals are estimated form the demand analysis and the availability from the hydrological model. The analysis shows a clear pattern in the upstream watershed, with the index values ranging from 0.1-0.2 during February-April indicating low to moderate scarcity, the same can be seen in the downstream reaches (see Figure 8a and b). Responses obtained from the field pointed that in the upstream reaches the people experience water shortage during February, March and April, which validates the above finding. However in the downstream areas, in addition to these three months, shortage was felt other times of the year too. As mentioned previously, the results are representative. it is important to note that availability does not guarantee access, especially in the downstream areas. Ensuring water security requires interventions at the structural and management levels.

Figure 8 : Water demand and supply comparison in the a. upstream and b. downstream watersheds



b.

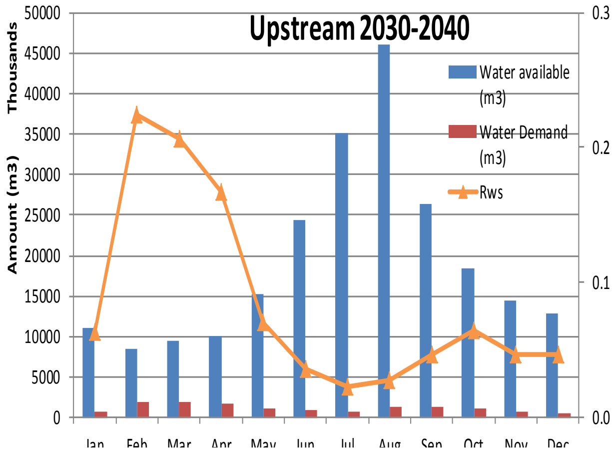


d. Future rainfall scenario analysis

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 input in the model to estimate availability. Water demand was modified by considering increased per capita water consumption (100 LPD). The results are shown in Figure 9 a and b.

Figure 9; Water demand and supply comparison in the a. upstream and b. downstream watersheds under future rainfall conditions (RCP 8.5) in 2030-2040

a.



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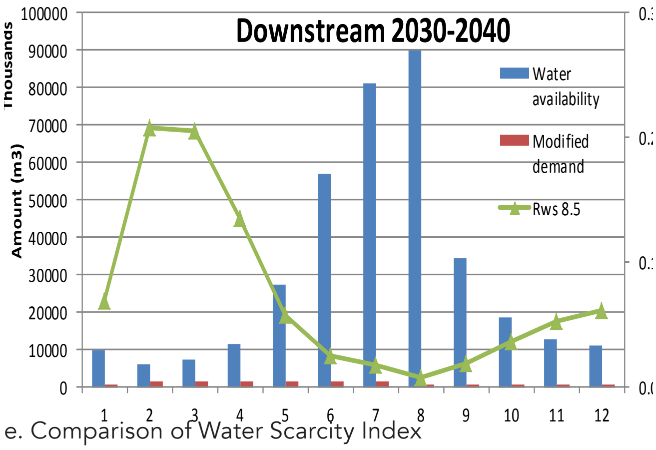
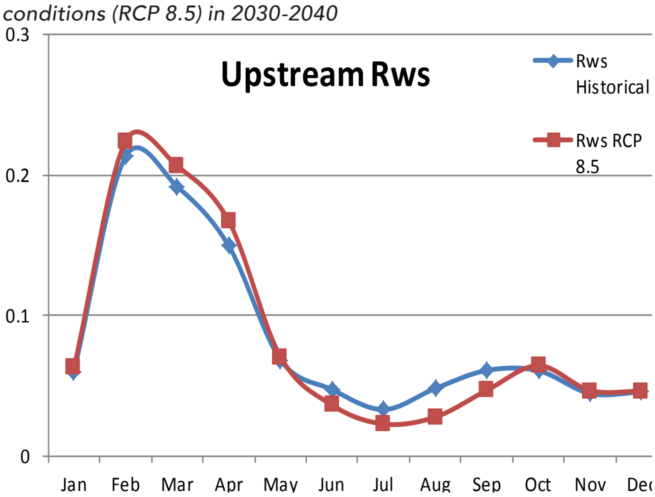


e. Comparison of Water Scarcity Index

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 (see Figure 10a and b). In the upstream watershed, the effect of interventions was explored for the upstream watershed, by doubling the number of storage ponds upstream. It was seen that compared to the Rws under business as usual for 2030-2040, the Rws values with additional storage showed a relative dampening of scarcity during the dry period (Figure 11).

Figure 10; Water demand and supply comparison in the a. upstream and b. downstream watersheds under future rainfall conditions (RCP 8.5) in 2030-2040



b.

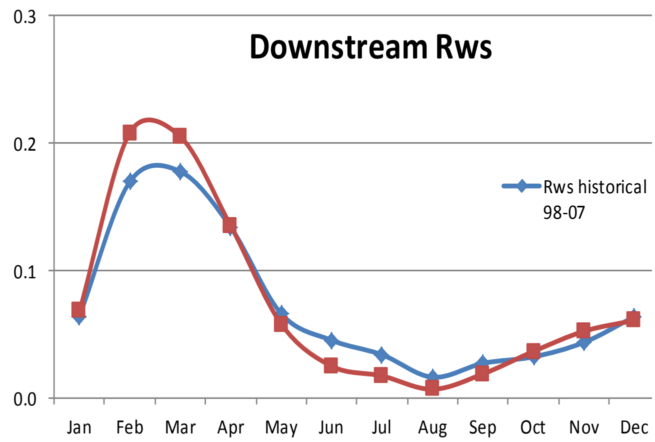
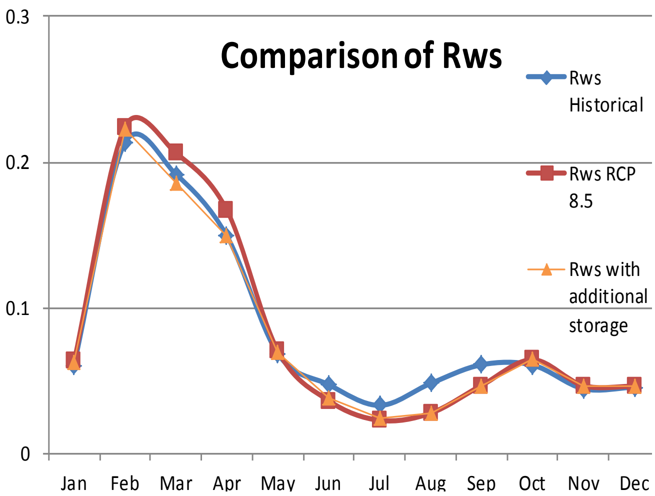


Figure 11: Comparison of Rws values obtained for 98-07, future rainfall (2030-2040) and additional storage under future rainfall conditions (2030-2040)



ANALYSIS

The effect of interventions, both structural and non-structural can be further looked into, however the issue on the ground is more dynamic. The question is whether such interventions can be introduced on the field. Implementation requires a clear demarcation and understanding between the stakeholders regarding headwater ownership.Dealing with water scarcity hence requires a more robust management structure, that incorporates the threats arising in the physical system coupled with the social threats.

Also, it is important to note that the downstream and upstream watersheds act as dynamic entities with associated properties, existing in the same system. Hence formulation of solutions needs a complete understanding of the entire system, alongwith specific information about the threats faced across different reaches of the system.

Considering the complex interconnected nature of the system, solutions need to be looked at on a basin level. Hence a nodal authority which makes decisions, looking at the entire basin in an integrated way could aid in easier, effective and coordinated decision making.

CONCLUSION

This research analyzed different components of the hydrological system in the area and clarified the contribution of the surface and groundwater flow in the area. The need to assess both, while also looking at the total water cycle, for estimating the availability of water in the system and the future changes, was identified as a key parameter for ensuring water security. Water scarcity was estimated in terms of the balance between availability and use, and it was found that there were periods of water scarcity in the area, with differences in the upstream and downstream reaches of the system. It has been shown that solving development challenges requires a multi-stakeholder strategy as the system is deeply intertwined with the social setup in the area, and the use of tools such as the water scarcity index can be done to aid effective problem identification and decision making regarding the timing and effects of interventions on the ground.

ACKNOWLEDGEMENTS

The authors extend their thanks to the Asia-Pacific Network for Global Change Research (ARCP2011-13NMY-Herath) for supporting the field research. The support of people of Hani rice terraces who helped in the field work is gratefully acknowledged.

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