

Simulating Socio-Economic Impacts of Climate Change on Rice Farming Systems: Trialing a Novel Integrated Methodology for Kadawaramulla, Kurunegala

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Introduction

More than 33% of Sri Lanka's population is directly or indirectly engaged in the rice sector (CBSL, 2011). Rice is produced in the Maha season (October to March) and the Yala season (April to September). Rice farms are generally small and crops are grown in complex, diverse and risk-prone environments. Climate change could have an impact on physical and biological systems (Rosenzweig et al., 2008) and rice productivity in South Asia is predicted to be reduced by 14% by 2050 (IFPRI, 2009).

The objective of this study is to assess a methodological approach to quantify the socio-economic impacts of climate change on rice dominated farming systems going beyond estimating net aggregate benefits and losses. Given the shortcomings of contemporary models, an integrated multi-model approach is called for. Here, we present a case of using one climate model, one crop model and one socio-economic model (all of which are state of the art) – to demonstrate the feasibility of using such models in an integrated framework under Sri Lankan conditions more substantially. We restrict ourselves to quantifying the potential number of farms that could gain or lose under a specific future climate change scenario without adaptation.

Objectives

Thus, the objectives of the study are: (i) to simulate historical climate and downscaled future climate projections needed for crop and economic modeling of rice; (ii) to implement the crop model for rice and simulate projections for future crop yields under climate change scenario; and (iii) to implement the Tradeoff Analysis Model (TOA) to assess economic impacts of climate change on rice based agriculture production systems in the Kurunegala district.

Methodology

The study carried out a farm survey in the Kurunegala district for the Maha season, 2011/2012. Data for yields, household and farm sizes, non-agricultural income, variable costs, prices, crop management activities, planting and harvesting were collected. The population represents rice farms in Kadawaramulla. For the selected sample, average size of farm and household sizes range from 0.2-1.0ha and 2-6 persons respectively. The methodology for this study could be generalized as a process to compare and assess the socio economic impacts of two climatic scenarios- one being the current climate and the other, with the effects of climate change (AgMIP, 2012).

Climate Modeling: The climate change scenario was generated using downscaling tools from Global Climate Models for 2040-2069 based on observations for 1980-2010 at neighboring Batalagoda. Variables, Maximum temperature (T_{MAX}), Minimum temperature (T_{MIN}), Precipitation and Solar irradiation were considered for the analysis.

Crop Modeling: In simulating yields for the climate change scenario, corresponding weather data were obtained from the climate models. Other major inputs, fertilizer and water applications for the specific farms were gathered through the farm survey where the relevant soil profiles, cultivar and crop growth inputs were gathered from relevant publications (e.g. Dharmarathna et al., 2012). Decision Support System for Agrotechnology Transfer (DSSAT) crop modeling software was used to simulate yields for the current and future periods.

TOA-MD Model: The Trade Off Analysis-Minimum Data (TOA-MD) model is a multi-dimensional impact assessment tool which utilizes statistics of farms (means, standard deviations, coefficients of variation) to

simulate the adoption and impacts of a change in environmental conditions on economic conditions (Antle & Valdivia, 2006). It seeks to assess the climate change impact on socio-economic aspects of farming systems with a minimal requirement of data.

The model was designed to simulate and compare two systems: System 1 denotes the baseline scenario and System 2, an altered system which is typically a modification of System 1. In TOA-MD simulations, assessment of economic gains/losses due to climate change would be based on the opportunity cost Δ , defined by,

$\Delta = V_1 - V_2$ while V_1 and V_2 are net gains from System 1 and 2 respectively. Where Δ follows a distribution $\Delta(\Delta)$, farmers would tend to gain from system 2 while $\Delta < 0$ and experience losses when $\Delta > 0$. In the case of climate change, $\Delta > 0$ would imply net losses due to the impacts of climate change.

In this study; **System 1:** This system corresponds to the base climate scenario (BCS) of 2011-2012. The farm survey data were utilized as the inputs for System 1 in the TOA-MD model. **System 2:** This system corresponds to the future climate change scenario (FCCS) of 2040-2069. As in System 1, farm survey data except for the yields were utilized as inputs for System 2. The yields for System 2 were derived from DSSAT simulations for the corresponding climate data simulations for 2040-2069.

Results

Climate simulation results show a positive deviation from the base climate in terms of T_{MAX} and T_{MIN} where DSSAT results for crop simulations shows a decrease with climate change (*Table 01*). TOA-MD results show a high proportion of farmers, as much as 83%, losing due to climate change (*Table 01* and *Figure 01*). The point where the curve cuts the x-axis marks the proportion of farms gaining due to the changed climate (*Figure 01*). The region left to this point represents the proportion of farms experiencing net gains where the region to the right represents the proportion of farms experiencing net losses.

Table 1: Climate, Crop and TOA-MD Analysis Results

Climate Results										
Scenario	Number of days	T _{MAX} (°C)						Precipitation (mm)		
		Mean	SD	95% CI	Mean	SD	95% CI	Mean	SD	95% CI
<i>Base</i>	731	30.98	5.20	± 0.38	22.60	8.96	± 0.65	4.71	17.17	± 1.24
<i>Future</i>	11323	32.85	1.82	± 0.03	25.03	1.86	± 0.03	4.93	13.36	± 0.25
Crop Results										
Yield Averages (Kg/ha)										
Base Climate Scenario (Observed)		Base Climate Scenario (Simulated)			Future Climate Change Scenario					
5573		4002			3750					
TOA-MD Results										
	Gains per farm (Rs)	Losses per farm (Rs)	As a percentage of mean farm returns				Percent losers(%)			
			Gains (%)		Losses (%)		Net Loss (%)			
Aggregates	615.5	5858.5	1.1		10.9		9.7	82.7		

Conclusion

According to the results from TOA-MD analysis, the impacts due to climate change could be quite substantial- around 83% of farms experiencing losses. Losses here simply represents the decrease of net farm returns due to climate effect. We find that this integrated climate-crop-economic modeling approach shows potential to use data that are typically available in Sri Lanka to assess the potential impacts of climate change at the farming system scale.

It is straightforward to extend this methodology to obtain other indicators such as income by farms and incorporate multiple crop, climate and economic models. Such work is being carried out. However, quality of the crop and climate data and simulations are placed equally important for the analysis to avoid any major biases. Parallel studies on improving the climate and crop results are carried out with different climate scenarios, crop calibrations and crop-climate sensitivity studies.

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