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The Impact of Climate Change on Agriculture – A Case Study from Nepal

In Nepal, as in many developing countries, concerns are increasing about the negative impact of climate change on agricultural yields and food security. The Nepalese have already seen changes in their climate that have made it increasingly difficult for people to feed themselves. Unfortunately, up until now, most studies on the impact of climate change on agriculture have been focused on more developed economies, so there is little relevant information for Nepalese policy makers to use.

Now a new SANDEE study has attempted to fill this information gap by analysing the impact of climate change on rice production in Nepal. The study is the work of Prakash Karn from Heifer International. Overall, it shows that climate change has already had a negative effect on rice yields and that by 2100, projected changes in climate could make Nepal's rice yield drop by about 4.2 percent relative to current levels. In light of these findings, the study recommends that future agricultural research should focus on the development of rice varieties that are tolerant of higher temperatures.

Climate Change and Nepalese Agriculture

Agriculture is a vital part of the Nepalese economy. It contributes to about a third of the country's GDP and involves about two-thirds of its population. Rice is the country's most important crop and accounts for about half of its total cereal harvest.

As said, guaranteeing food security is becoming an increasing challenge in Nepal. This is partly due to population growth, to an increase in the demand for food and to insufficient growth in farm productivity. Changes in the country's climate have also aggravated concerns over rice production and food security. For instance, the maximum temperature in Nepal increased by 1.8°C over the period between 1975 and 2006, and rainfall has become more erratic. Climate-related changes have also been observed in high intensity floods, landslides, erosion and increased sedimentation. Changes in seasonality have also been observed.

Given the subsistence nature of Nepal's economy, a slight decline in rice yields can have a devastating impact on household food security. Some farmers have begun to put in place adaptation measures. For example, some have changed cropping patterns and resorted to alternate sources of irrigation. However, it is clear that more needs to be done to prepare the country for the potential impact of climate change.

The study focus and research area

In order to see what impact future changes in climate will have on food production and food security in Nepal, the study focused on the country's key crop, rice, and asked two main research questions: a) How sensitive is the current rice yield in Nepal to changes in different climate variables? b) How is climatic change likely to affect rice production in the future?

To answer the first question, the study assessed how past changes in weather patterns have affected the yield of Nepal's summer monsoon rice crop. To answer the second question, the study used its findings on the relationship between climate and crop productivity to assess the impact of future climate change scenarios on rice yields.

This policy brief is based on SANDEE working paper No. 85-14, 'The Impact of Climate Change on Rice Production in Nepal' by Prakash K. Karn, Planning Monitoring and Evaluation Manager, (Climate Change Focal Person), Heifer International Nepal, Hattiban, Lalitpur, Nepal. The full report is available at: www.sandeeonline.org

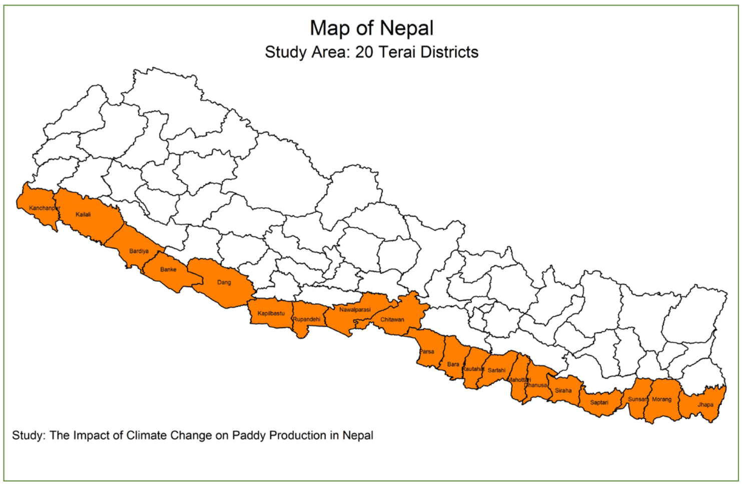
The Impact of Climate Change in South Asia

Numerous empirical studies suggest that climate change will have a bigger impact on agriculture in developing countries than in developed countries. However, the scale of this impact will depend upon the magnitude of the climate change. It is generally agreed that increasing temperatures will directly impact crops by affecting their physiology. Higher temperatures will also indirectly affect crops through changes in the water regime and due to the increase in the intensity of pests and diseases they will produce. Crops are also bound to be affected by more intense rainfall and other extreme weather events.

Projections of likely increases in seasonal surface air temperatures and seasonal precipitation levels suggest that there will be a significant acceleration in warming in South Asia and that this will be greater than the rise that was observed during the 20th century. The warming, moreover, is projected to be strongest in the Himalayan Highlands (including the Tibetan Plateau) and in the arid regions of Asia. Studies further project an increase in the inter-annual variability of daily precipitation in the Asian summer monsoon.

There has already been an increase in the frequency and intensity of rainfall events in many parts of Asia, which have been largely attributed to increasing temperature. These climate changes have caused severe floods, landslides and mud flows. However, the frequency and intensity of droughts seems also to have increased, particularly during the summer and the normally drier months. There is also concern that glacier melt in the Himalayan region will increase flooding and affect water resources within the next two to three decades. This melting would inevitably be followed by decreased river flows as the glaciers recede. The warmer climate is also expected to lead to a higher intensity of extreme weather events, which will increase the risk of flash floods in parts of Nepal.

Available studies offer differing estimates of the impact of climate change on crop production in Asia (due to increasing temperature and water stress). Many studies show that increases in atmospheric CO_2 can significantly stimulate growth, development and reproduction in a wide variety of plants including rice. However, projections using HadCM2 indicate a likely decrease in crop yields of up to 30 percent in South Asia, even when the direct positive effects of CO_2 are taken into account. Lal (2007), for example, projects a decline in net cereal production of at least 4-10 percent by the end of the 21st century under the most conservative climate change scenarios. While agronomic studies in India suggest that a temperature rise of 4°C would cause a fall in grain yields of 25-40 per cent. Overall, it is clear that, when all factors are taken into account, climate change is likely to have a negative impact on agricultural yields in South Asia.



Nepal has three broad ecological regions: the Himalayas in the north; the hills and valleys in the middle; and the Terai, which is an extension of the Indo-Gangetic plain in the south. The Terai plains constitute the major food basket of the country, as two-thirds of Nepal's total rice area is grown in the Terai and nearly 70 percent of its total rice production comes from the region. Given the importance of this area to rice production in Nepal, it made the obvious focus for the SANDEE study.

The Terai region includes 20 out of Nepal's 75 districts. It is bound to the north by the Churia hills and to the south by the Indian border. According to the 2011 national census, the Terai covers roughly 17 percent of the country's land and is inhabited by approximately 50.3 percent of Nepal's population. The Terai region has experienced significant climate change in recent years. For example, between 1977 and 1994, the Terai experienced an average increase in annual temperature of 0.04°C/yr.

Data on rice yields and weather changes

The study used information from all 20 districts in the Terai region. This information covered annual rice yields and daily observations on weather variables. The data on agricultural output was collected from various district level government agencies such as the Department of Irrigation and the Department and Ministry of Agriculture. It included annual observations on cultivated and irrigated areas and yields. It covered a 25-year period (1984 – 2008). Data on weather variables was obtained from the Department of Hydrology and Meteorology, which collects and maintains data from all of the study districts. The weather data comprised daily data on maximum and minimum temperatures, rainfall and morning and afternoon humidity for the period between 1968 and 2008.

Climate trends in the study region

The data showed that there had been a clear pattern of increasing temperatures for each rice growth phase over the 40-year sample period from 1968 to 2008. This is a key finding as high temperature

Figure 1: **Average Total Rainfall across Years during Different Growth Phases**

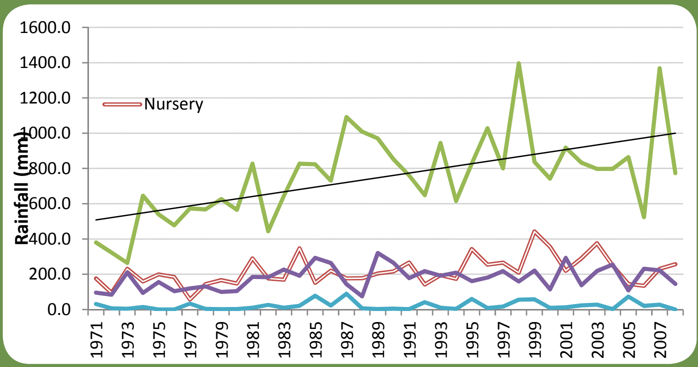
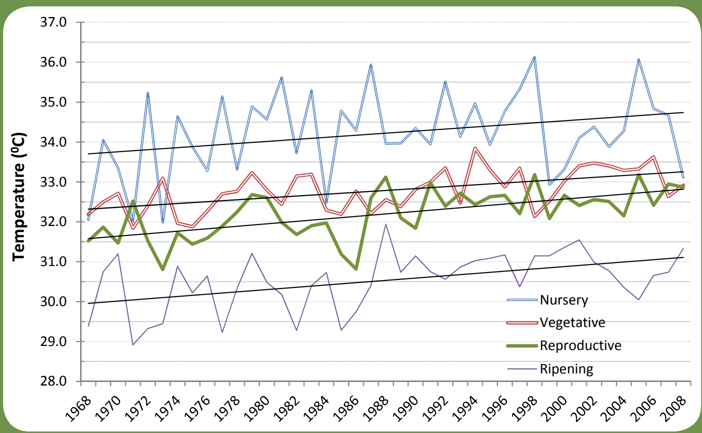


Figure 2: **Temperature (max) during Rice Growth Phases across Years**



Rice has four stages in its development. These are the nursery, vegetative, reproductive and ripening stages. Changes in weather lead to changes in when farmers plant and harvest rice. This in turn modifies how the rice crop develops during each stage of its development. Therefore, in order to understand the effect of climate on rice development, the study first used the data at its disposal to identify rice establishment and harvest dates and to chart the weather changes in each of the different crop development stages.

is one of the major environmental factors limiting the growth and yield of rice. For example, high temperatures during the flowering phase can lead to complete sterility, while high temperatures during the vegetative and ripening phases can alter grain quality.

The data also showed that there was a slightly increasing trend in average total rainfall from west to east during the rice crop's nursery, reproductive and ripening phases, along with a slightly decreasing trend during its vegetative phase. Time trends showed that the average total rainfall seems to have remained almost the same during the nursery, reproductive and ripening phases although a clear increasing trend has been apparent during the vegetative phase.

The impact of the climate on yields

Using this data, the study assessed the impact of climate on rice yields. The impact of temperature, rainfall and humidity were all considered.

The study found a robust and significant non-linear relationship between maximum daily temperatures and rice yields. Its findings show that rice yields are most sensitive to increases in daytime maximum temperature. Specifically, the study finds that a 1°C rise in daytime maximum temperatures during the ripening phase increases rice harvests by 27 kg. ha^{-1} up to a cut-off point of 29.9°C. However it also finds that productivity declines and yields are harmed when daytime maximum temperatures go beyond 29.9°C.

The study highlights the fact that the average maximum temperature in the study region for the decade between 1999 and 2008 was 30.8ºC. The study results suggest that rice productivity declines when temper-atures increase beyond 29.9 degrees C. Thus, it is expected that rice yields have already been harmed by high daily maximum temperatures. It is therefore likely that rice yields will diminish if there are any further increases in maximum daytime temperatures.

The study also found that rainfall appears to have a significant effect on rice yield. Specifically, it finds that precipitation has a negative effect on yield if rainfall increases in the nursery stage of the crop's growth. Higher morning humidity also harms rice growth, while afternoon humidity helps improve growth.

SANDEE

The South Asian Network for Development and Environmental Economics (SANDEE) is a regional network that seeks to bring together analysts from the different countries in South Asia to address their development-environment problems. Its mission is to strengthen the capacity of individuals and institutions in South Asia to undertake research on the inter-linkages among economic development, poverty, and environmental change, and to disseminate practical information that can be applied to development policies. SANDEE's activities cover Bangladesh, Bhutan, India, Nepal, Pakistan, and Sri Lanka.

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The impact of future climate change

The study's prediction of future changes in rice yields used two sets of climate projections. The first set of projections was based on high-resolution climate data from the National Center for Atmospheric Research (NCAR) climate model CCM3. This model assumes a double CO_2 emissions scenario and estimates climate change up until the year 2100. The model predicts that by 2100 the maximum temperature during rice's ripening phase will be 32.5°C (or a 1.6°C increase on current temperatures). It also predicts that rainfall at this time will be 283.9mm (a 89.3mm increase).

The second set of projections came from the Nepal Climate Vulnerability Study Team's dataset. This predicts temperature increases of 1.4 °C, 2.8 °C and 4.7 °C for the years 2030, 2060 and 2090 (relative to the period 1970-1999). In this dataset, projected mean annual rainfall does not show a clear trend and varies widely, but it does predict an increase in rainfall towards the end of the century. The increase in annual rainfall projected for 2030, 2060 and 2090 is 2%, 7% and 16% respectively (relative to the base period of 1970-1999).

Using the first set of projections, the study estimates that by 2100 rice yields will decline by 4.2 per cent relative to current levels (a decline in rice yields of 104 kg per ha). The second set of models predicts that rice yields will fall by 1.5 per cent by year 2030, by 4.2 per cent by 2060 and by 9.8 per cent by 2090. These findings are in line with many other studies that have also projected a reduction in crop yields ranging from 3 to 30 percent in the future (see side bar for more details).

Policy recommendations

It should be noted that the study ignored positive long-term effects of CO_2 fertilization, which should occur as levels of the gas rise. At the same time, the study did not consider other negative effects triggered by climate related changes, such as an increase in extreme events, including droughts, storms, soil erosion and avalanches. Nor did it take into account technological developments that may counteract some of these adverse effects and so improve productivity.

Two important recommendations emerge from this work. Firstly, since a rise in temperature beyond a critical threshold level seems to have a negative effect on rice yields, the study recommends that future agricultural research should focus on the development of high-temperature–tolerant rice varieties. Secondly, the study was hampered by a lack of information on solar radiation and by a lack of reliable data on economic variables such as prices. Thus, the study also recommends that a more comprehensive assessment (or field experiment) that factors in the missing weather and economic variables would help improve understanding of the impact of climate change on rice yields.

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