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ICARDA
Science for Better Livelihoods in Dry Areas

Research Brief 4

# Measuring climate change impacts on farm income in Central Asia

## The Challenge

**Despite serious influences of climate change on food security and farm income, there is insufficient research in Central Asia on the impact of climate change on agro-ecosystems, farm incomes, and analysis of the potential adaptation strategies. There is very limited use of integrated assessments critical for analyzing environmental, economic and social trade-offs in adaptation options.**

**To provide insights and rationally convince policy makers about the impacts of climate change on the agricultural economy and elicit adaptive measures, a study was conducted to measure climate change impacts on farm income in Central Asia. It fills an important knowledge gap using integrated assessments for analyzing environmental, economic and social trade-offs.**

## Measuring climate change impacts on farm income in Central Asia

Impacts of climate change on the agricultural economy are being experienced by farmers and herders around the world. However, the question being currently debated is how big will be the overall effect of climate change on the agricultural economy? The increasing interest in climate change heightens the need for an agro-economic model to analyze climate change impacts on farmers' incomes.

To scientifically measure the impact of climate change on agro-ecosystems and farm income, a study was undertaken by ICARDA[1] in cooperation with the International Food Policy Research Institute (IFPRI) and funded by the Asian Development Bank and later expanded to align with the CGIAR Program on Climate Change, Agriculture and Food Security (CCAFS). The goal of this study was to assess the impacts of climate change (CC) at the farm level in CentralAsia (CA) with a focus on three main crops (cotton, potatoes, and wheat) which are crucial for rural economies and food security in Kazakhstan, Kyrgyzstan, Tajikistan and Uzbekistan (Photo 1).

*Photo 1: A potato farm in Tajikistan, reeling under climate uncertainties (Photo courtesy: IWMI)*

## Bio-economic Farm Models for analyzing climate change scenarios

The study applied integrated models (also known as Bio-economic Farm Models, or BEFM) which are capable of simultaneous consideration of biophysical changes and management decisions in different farming systems, and are suitable for analyzing the impacts of climate change on the whole farm or sector. Integrated models also allow the possibility of combining with agro-ecological zoning approaches, since they can be made spatially explicit. Integrated models also assist in analyzing complex functional relationships between agro-ecological characteristics (e.g. soil type and fertility) and farm level decision making (e.g. input use, technology choice) under climate change scenarios.

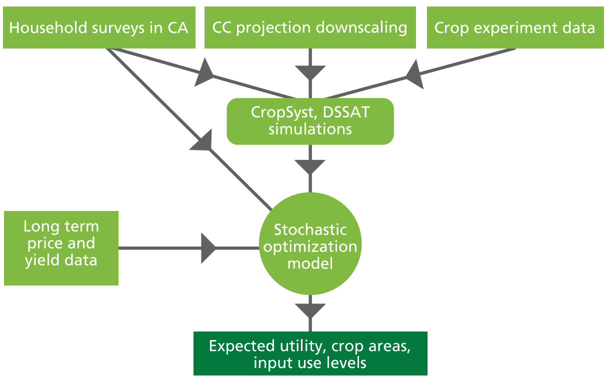


*Figure 1: Bio-economic farm model (BEFM) components*

The integrated model applied for this study (Figure 1) consisted of three main components: (1) climate change projections, (2) yield impacts though crop simulations and (3) economic impact assessments. The climate change scenarios were spatially downscaled to the local levels. From the 23 General Circulation Models (GCM) available at the time, seven most advanced models were used to downscale precipitation, minimum, maximum and mean temperature changes under these scenarios for different future time periods. The downscaling was implemented by overlaying coarse-gridded GCM change fields into current high-resolution climate grids.


*Figure 2: The farming systems of Central Asia*

This method yielded results close to the observed situation, even in areas with complex topography, and directly generated climate surfaces. The downscaling method provided absolute deviation of monthly temperature and relative deviation of monthly sum of precipitation from historic data for two future periods (near future: 2010–2040; and late future: 2070–2100). Results showed an expected increase in temperature and precipitation in all considered

[1] For details of this research see I. Bobojonov and A. Aw-Hassan (2014). Impacts of climate change on farm income security in Central Asia: An integrated modeling approach. Agriculture, Ecosystems and Environment 188 (2014) 245–255.

farming systems but the magnitude of changes differed among the farming systems (Figure 2).

The yield impact of climate change was measured with crop simulation models which used these downscaled scenarios. Since crop models require daily time step data, stochastic weather generators (WGs) are commonly used for estimating daily data. The LARS-WG[2] was chosen as the most suitable weather generator for Central Asian climate for producing the required daily step data. These crop simulation models were calibrated with the crop experimental data as well as actual farm management practices collected from farm surveys. CropSyst and DSSAT models[3] were used to assess the impact of climate change on crop yields. These models were calibrated for each of these countries and selection of the locations was done according to the importance of the farming systems in production of wheat, cotton and potato. Data on crop experiments conducted by national research institutes in Central Asia was obtained in order to calibrate the crop simulation models.

The results of the crop simulation models (yield impacts) were then used in the economic impact assessment component of the integrated modeling. Farm-level stochastic-optimization model was developed and used to identify the climate change impact on farm income volatility and potentials for different management options to improve farm income.

In this study, the expected value-variance (EV) framework approach was used to analyze risks associated with different agricultural decisions such as crop allocation and input use levels. In the EV approach, the choice of activities or enterprises with the highest utility for the farmer was determined taking into account the variability of utilities and their covariance across different crop enterprises. The EV was used to analyze the impact of climate change and the resultant farmer responses especially with regard to area allocation and resource use decisions. The BEFM model determined optimal cropping area allocation and optimal input use levels under different climate scenarios. The main criteria for identification of the optimal mix of activities were the expected income and variance of income for each type of activity. The model objective function which maximizes the expected utility (EU) (also known as certainty equivalent, CE) as considered in many bio-economic models in the past, was given by the following equation:

$$max\,CE = E(Y) - \frac{\lambda}{2}V(Y)$$

**Subject to:** $B_j \geq \sum_{i=1}^{n} a_{ji} H_i$

*where E(Y) represents the total expected income (expected returns minus costs) of the farm, V(Y) is the variance of the income and λ is a parameter that represents the coefficient of absolute risk aversion, Bj is the availability of jth resource (e.g. fertilizer, irrigation water), aji is input use coefficient for crop i, and Hi is the area under each crop.*

## Gains and losses in the near and far future

The main finding of this study was that climate change impacts on agricultural systems in Central Asia differ depending on agro-ecological zones and socio-economic aspects (Figure 3). Farmers in Uzbekistan will benefit from climate change due to more favorable weather conditions for crop growth in the near future (2010–2040). However, their revenues are expected to decline in the late future (2070–2100) due to increasing temperatures and increasing risk of water deficit, especially if availability of irrigation water declines. There might be a slight increase of expected revenues in semi-arid zones of Kazakhstan. Some increase in revenues is also expected in the arid areas of Kazakhstan which will not increase the farmers' utility due to the expectation of higher variances in crop yields associated with climate uncertainties.

In contrast, farmers in sub-humid zones are expected to benefit from increasing temperature and precipitation. Impact of climate change on income of Kyrgyz farmers in semi-arid zones will be neutral in the near future, but is expected to be positive in the late future. Farmers in sub-humid zones of Kyrgyzstan will probably have higher expected income under all emission scenarios in near and late future years. However, this might not increase their benefits since additional gain is prone to increased risk associated with weather extremes. In Tajikistan, impact of climate change is crop specific. Wheat revenues may not change in the future, but income from cotton will decline due to a decline in yields if current levels of management are maintained. Potato farmers may receive higher revenues in the future as yields are expected to increase.

[2] LARS-WG is a model simulating time-series of daily weather at a single site.
[3] These agronomic models are well-known tools used to analyze the impact of biophysical environment, management practices and climate variation on crop yields.

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Overall, the impact of climate change is positive in the semiarid and humid zones of Tajikistan, but producers in the arid regions may suffer from losses under climate change scenarios. Scenario simulations with the condition of market liberalization show great potential for policies to enable producers to mitigate negative consequences of climate change, especially in Tajikistan and Uzbekistan. It was also concluded that more open economic policies and less rigid trade policies can be effective adaptation strategies as trade barriers may limit farmers to shift to export crops or impose production of uncompetitive crops even if they are more likely to be affected by climate change.

These changes in farm income, as reflected in the findings of this study, will go a long way in helping policy makers take decisions that can provide adaptation measures. A long term view can give insights into production and marketing policies that will help farming communities to adapt to climate change and safeguard their interests.

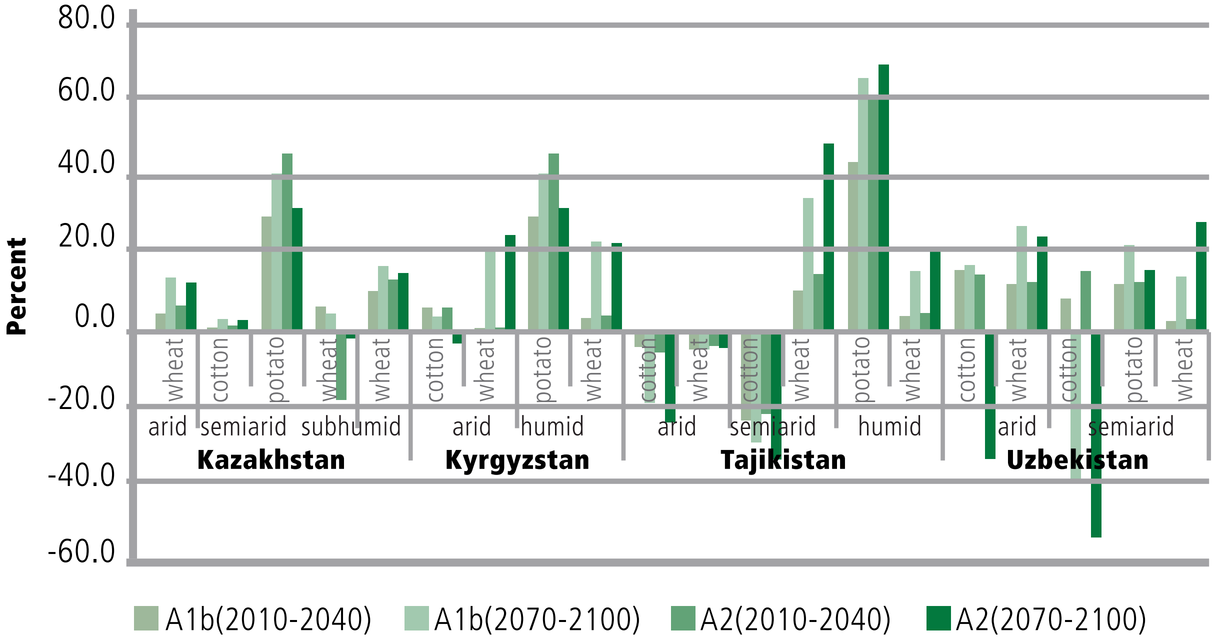


*Figure 3: Crop yield changes (in percent) under average input use levels compared to the baseline scenario*

### ICARDA's Sustainable Intensification and Resilient Production Systems Program

ICARDA's Sustainable Intensification and Resilient Production Systems Program (SIRPS) integrates biophysical, socio-economic and policy research in order to ensure the emergence of more efficient and sustainable food production systems. It promotes income generating options for the rural poor from crops, and livestock (mainly small ruminants), by improving and diversifying current agricultural production systems.

**A partnership of:**

ICARDA Science for Better Livelihoods in Dry Areas

ADB

IFPRI

CGIAR Climate Change, Agriculture and Food Security CCAFS

**In collaboration with the National Agricultural Research Systems of:**

- Kazakhstan
- Kyrgyzstan
- Tajikistan
- Uzbekistan

**Project contact:**
Aden Aw-Hassan, Team Leader-Socio-Economics Component, Sustainable Intensification and Resilient Production Systems Program, ICARDA, a.aw-hassan@cgiar.org

International Center for Agricultural Research in the Dry Areas
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