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PA33E-1137: Integrative Economic Evaluation of an Infrastructure Project as a Measure for Climate Change Adaptation: A Case Study of Irrigation Development in Kenya

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*This study was financed by the JICA Research Institute (JICA-RI). DN's research was supported by JSPS KAKENHI, Grant-in-Aid for Scientific Research (Grant Numbers: 17KT0066 and 17K00677)

Study Background and Main Points

- In the presence of the needs for development assistance regarding climate change adaptation (e.g., in terms of Paris Agreement), there are also the needs for evaluation methods for adaptation projects reflecting uncertainty of climate change
- As a demonstration of project evaluation in terms adaptation effectiveness, we conduct a case study of a Kenyan irrigation development project (a project financed by the Japan International Cooperation Agency, JICA), estimating local effects of climate change with and without the project through a combination of climate, hydrology, yield and economic simulations.
- Results show general increases of farmer's income and yield with irrigation development under climate change, while they also exhibit a great degree of uncertainty.
- These patterns may imply overall effectiveness of irrigation development as an adaptation measure to climate change, especially in the sense that it moderates the worst-possible outcomes

1. Scope of the study

As climate change adaptation is becoming a recognized policy issue, the needs are growing about quantitative economic evaluation of adaptation-related public investments, particularly in the context of climate finance. Irrigation, which enhances and stabilizes water supply for farming, is a potential means of climate change adaptation, but attempts of economic evaluation of its effectiveness as an adaptation measure are few in part because such assessment requires an integration of various types of simulation analyses. Against this background, we conduct a case study of a Kenyan irrigation development project to evaluate the effectiveness of the project for climate change adaptation by using a combination of simulation models. Specifically, we conduct a simple downscaling of CMIP5 climate simulation data, whose outputs are fed into a hydrological model (SHER model) and a yield forecasting model (DSSAT model). With these simulation data, together with data of socioeconomic parameters drawn from existing and original surveys, we compute economic variables such as farmers' average income. Climate and other uncertainties are incorporated into analysis without probabilistic weights (conforming to the Robust Decision Making (RDM) approach, e.g., Lempert et al., 2013) to highlight vulnerabilities for local farming.

2. Study approach

We conduct a case study of the Mwea Irrigation Development Project, which is an irrigation dam project in Mwea area of Kenya (See Figure 1 below) undertaken by Kenya's National Irrigation Board (NIB) with a loan provided by the Japan International Cooperation Agency (JICA). Irrigation farming of rice and horticulture has extensively been carried out in the area, and the dam project is to increase and stabilize water supply for the farming (the yellow areas in Fig. 1(b) are existing farmlands, and the green parts are extension areas). In this analysis, we evaluate the effectiveness of the project on climate change adaptation defined as the difference in output quantities (e.g., yield) with and without the project under climate change relative to the difference that would be expected in the absence of climate change. Economic metrics (income, etc.) are estimated by using multiple simulation models, namely, climate, hydrological and yield forecasting models, which are soft-linked with each other (i.e., do not reflect all interactions across models). Water balance analysis and economic analysis are conducted by using outputs of these models and also reflecting actual local conditions of cropping patterns (cultivation of rice, maize, tomato, etc., in the long and short rainy seasons), practiced water allocation regimes in the locality, population, etc. Simulations are performed for a number of scenarios on the climate and socioeconomic parameters, which represent uncertainties (see Figure 2). Uncertainties are systematically assessed by using the methods of RDM, while conventional metrics of cost-benefit analysis are also calculated (results not shown on this poster).

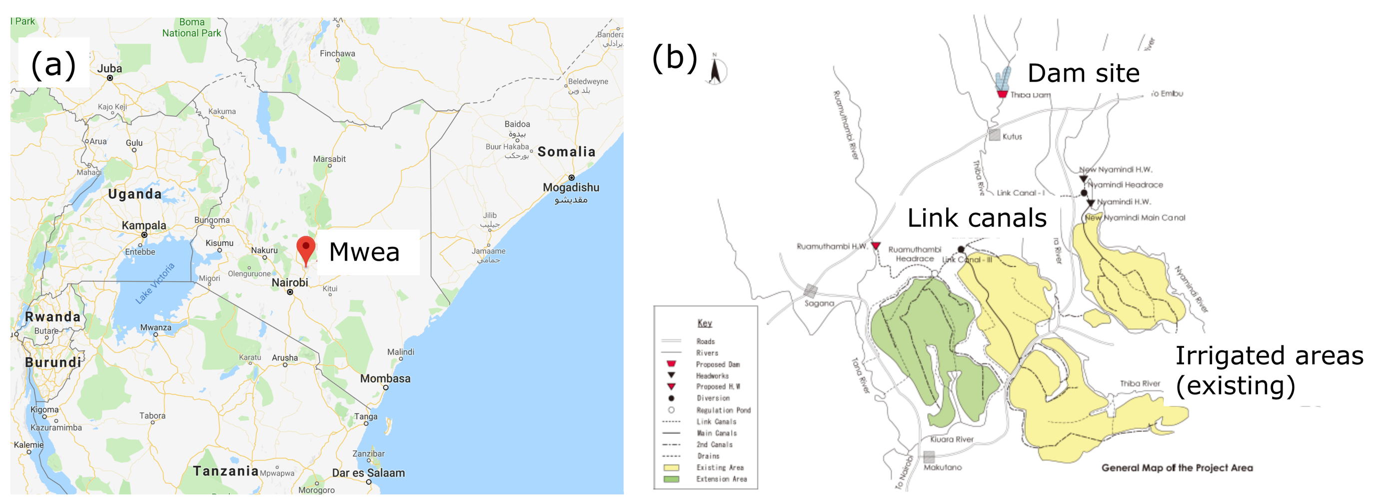

Figure 1 *(a) Location of Mwea, Kenya (Google Maps) and (b) Map of the project area*

Economic analysis is carried out for a hypothetical case without an irrigation dam ("donothing") and for four options of possible cropping patterns after the irrigation development project is completed, named "RiceRice," "RiceUpland," "RiceRice+," and "RiceUpland+," which differ in crops grown in the long and short rainy seasons in the area (whether to focus on rice or to grow various upland crops besides rice) and in adoption of the improved farming practices and techniques proposed by a previous agricultural research project in Mwea (the WSRC and the IRaP: "+" in the option names signifies the adoption of these techniques). By using data of a prior survey and our originally surveyed data, we identify levels of key socioeconomic parameters such as crop prices and the number of farming households.

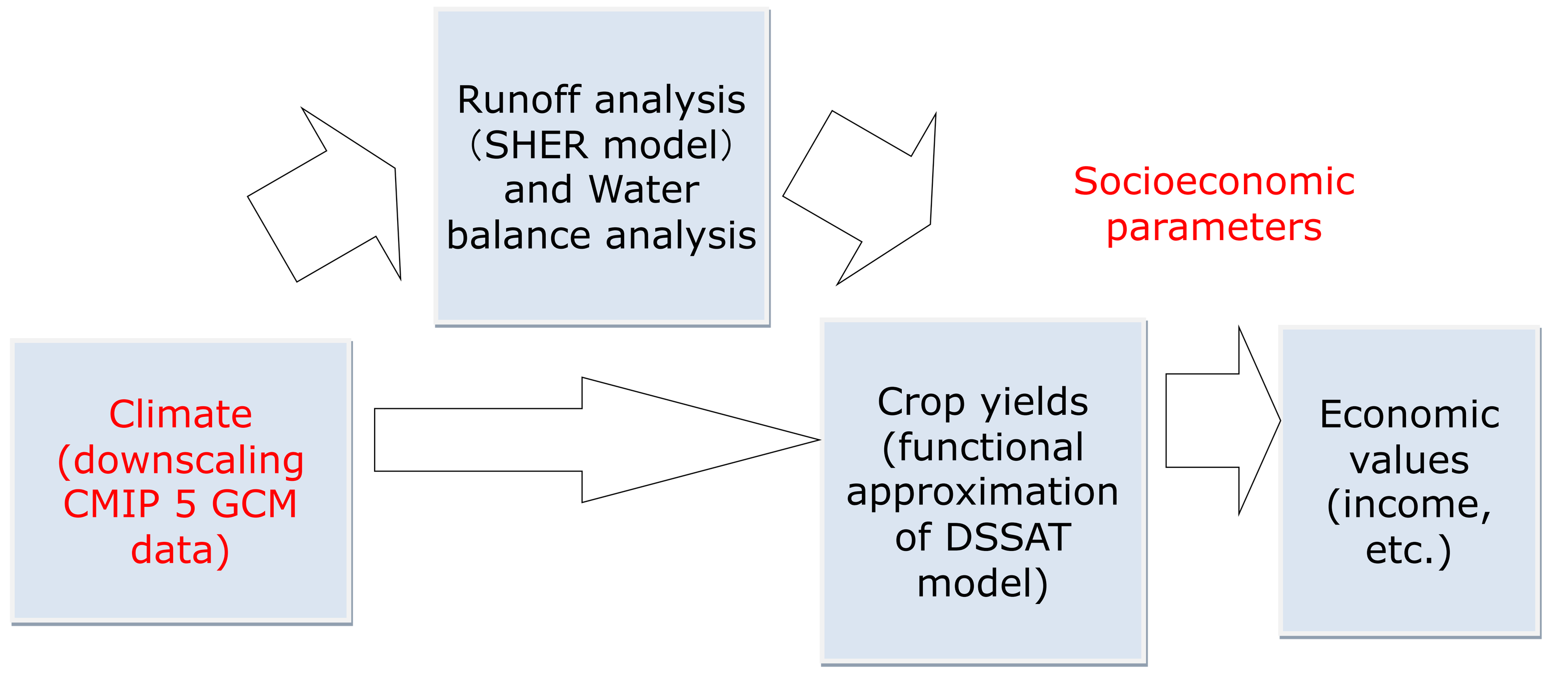

Figure 2 *Flow of our simulation analysis. We conducted this set of simulations for 24,000 cases with different climatic values and socioeconomic parameters (marked in red), for which cases are randomly generated and selected by Latin Hypercube Sampling.*

3. Simulation results

Figure 3 shows simulation results on farmers' annual income of Mwea (the target region) for the four options with the irrigation development project and for the case without the irrigation development project (donothing). The Figure shows that estimated income levels for the four options with the irrigation development project are generally higher than those without the irrigation development project, although some overlaps in the range of boxes and whiskers exist. Adoption of improved farming techniques also leads to generally higher levels of income relative to the cases without them.

Effects of climate change are made more visible in Figure 4, which isolates the relative changes of rice yields in Mwea from the baseline levels that assume no climate change. Results are shown as percentage changes from the baselines. The dotted horizontal line corresponds to zero change (no effects of climate change), and the boxes represent changes from the baseline under different climate and socioeconomic scenarios. Overall, the plots indicate great uncertainties about climate change impacts, with many areas both below and above zero for all the five sets of results. However, especially for 2050, the general tendency of negative yield changes under climate change is clear. For 2050, relative to the donothing results, the distributions for the other four options are generally located higher both in yield and income, and many scenarios of the four options with irrigation development exhibit positive income changes due to climate change. These are an indication that the irrigation development project mitigates the negative effects of climate change, in other words, it serves as an effective means of climate change adaptation.

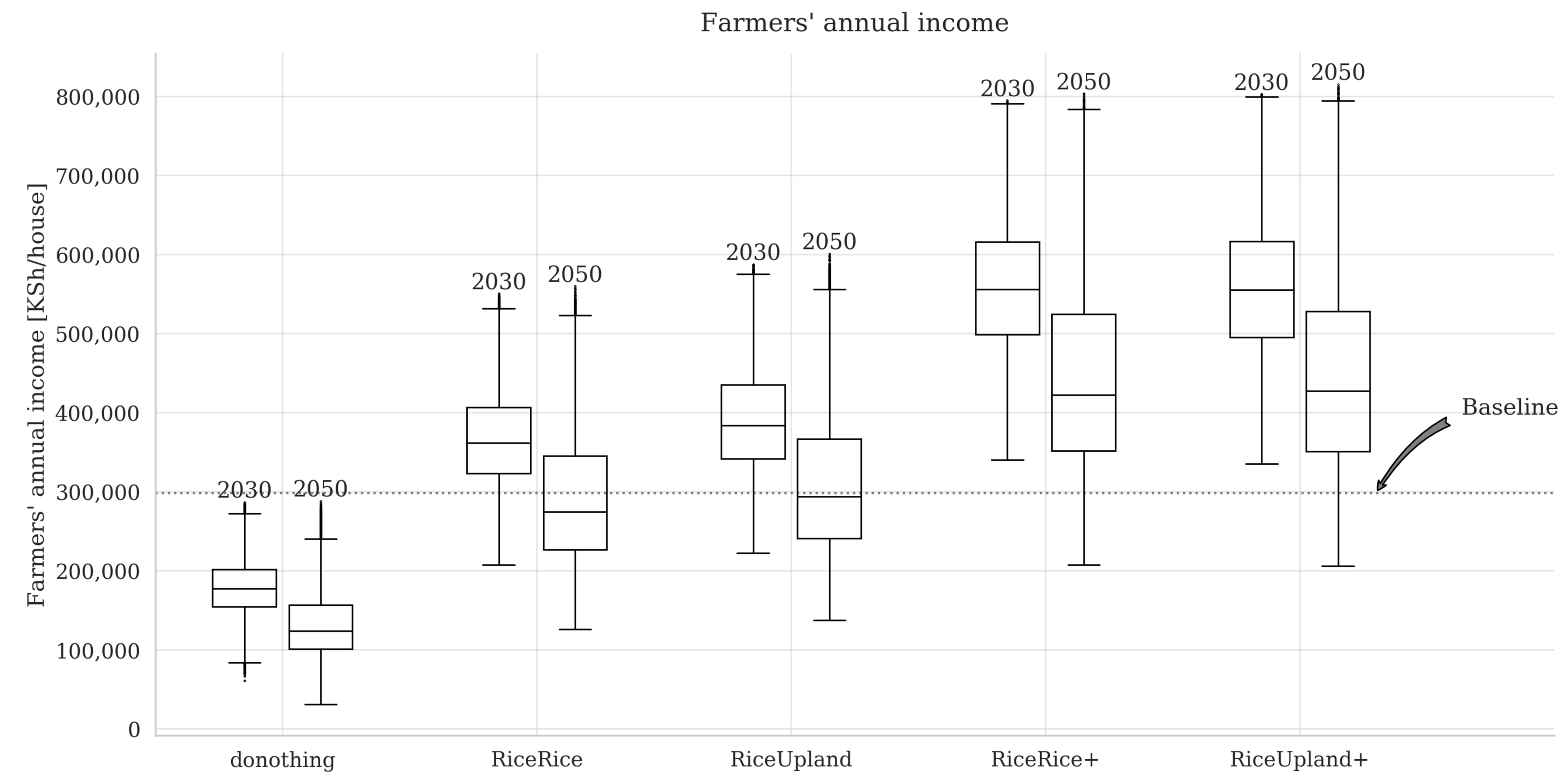

Figure 3 *Simulation results of farmers' average annual income in the target region (Mwea). The ends and middle lines of the boxes correspond to the quantiles (i.e., the middle line represents the median) of all simulated cases, and the whiskers represent the 1.5 interquartile ranges (IQRs). The dots above and below whiskers represent the outliers. The baseline corresponds to the current level of average annual household income in Mwea.*

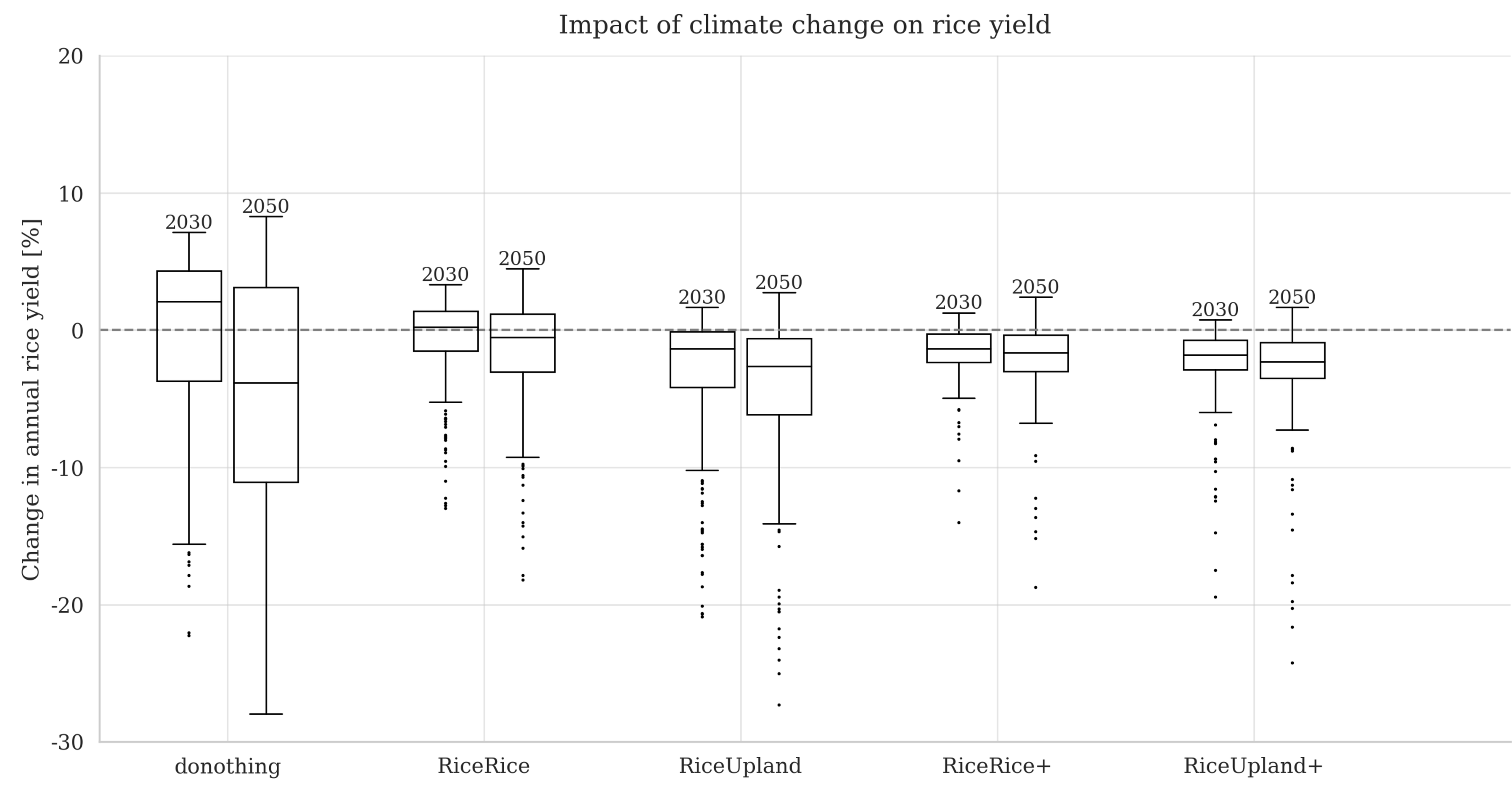

Figure 4 *Impact of climate change on the rice yield in the target region (Mwea). (percentage changes under climate change relative to the levels without climate change). The ends and middle lines of the boxes correspond to the quantiles (i.e., the middle line represents the median) of all simulated cases, and the whiskers represent the 1.5 interquartile ranges (IQRs). The dashed line represents the level of zero impacts of climate change.*

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