Crop choices under climate change in the Danube River Basin

Agricultural land allocation remains sensitive to climate change. As temperatures rise and precipitation patterns become more variable, farmers switch to crops better suited to the changing climate. This substitution has tremendous market and welfare implications. Using field-level data on cropping practices, we investigate how crop choices alter under climate change. First, we estimate a yield-weather model to identify crop-specific thresholds for extreme weather and predict the impact of climate change on yields. Results are then integrated into a crop choice model to identify the key variables influencing farmers' decisions and simulate how choices differ under various climate scenarios.

The role of climate change in driving land-use changes is a relatively understudied topic. Some efforts have found evidence of switching away from wheat and cotton to more profitable corn and soy cultivation (Cui, 2020), while others have found displacement of cropland by grass due to reduced yields of commodity crops (Arora, Feng, Anderson, & Hennessy, 2019). The current studies, however, are conducted at an aggregated level which fail to capture farmers' decisions-making process that is undertaken at the field-level. Moreover, because of the lack of data, these studies often use aggregated measures such as county or state-level profits or prices that inaccurately measure the impact that crops' profitability has on farmers' choices. This imprecision introduces measurement-error bias that may underestimate the true effect of profits on crop choices. Through this paper, we improve on the previous literature by using field-level data for crops and yields for 2,760,567 fields across Serbia that allows us to accurately capture the heterogeneity in farmers' decision-making that is often lost in aggregated studies. By converting field-specific yields into a productivity variable and adjusting it for climate change, we also account for how shifts in future productivity, that impact net crop returns, influence predicted crop choices.

We use remotely sensed pixel-level yield data from 2017-2022. Pixel-level crop data on maize, wheat, soybean, sugar beet, sunflower, and rapeseed are obtained from Landsat and Sentinel-2 images for 2018-2022. We convert our pixel to field-level data using a cadastral map of field boundaries, classifying fields by the majority crop category. Field-specific yields are obtained by taking crop-specific weighted averages of all the pixels within a field boundary. Data on daily temperature, obtained from E-OBS from 1988-2022, is converted to 5°Celsius bins for our yield model to represent the total number of days in each temperature range during the growing season. For our crop choice model, we incorporate mean temperatures along with crop-specific heat and cold stress variables created using thresholds obtained from the yield model. Data on monthly soil moisture and precipitation are obtained from running a Soil and Water Assessment Tool-Plus (SWAT+) Model. Future climate projections (1981-2100) are obtained from bias-adjusted regional climate simulations based on EURO-CORDEX. Crop-specific profits are constructed using survey data on revenues and costs of production obtained from 728 farmers in Serbia for the period of 2015-2020 (BioSense Institute, 2022).

We estimate the yield weather model (1) separately for each crop category using a fixed effects panel estimation with yields, Y_{it}, for field i and year t ranging from 2017-2022 as dependent variables and j representing each temperature bin:

$$\ln(Y_{it}) = \beta_0 + \sum_{1}^{7} \beta_j MaxTempBin_{j,it} + \alpha_1 Precip_{it} + \alpha_2 Precip_{it}^2 + \gamma Year + \mu_i + \varepsilon_{it} \quad (1)$$

For our crop choice model, we estimate the probability of a crop being chosen which depends on current profits that are estimated using a conditional logit framework,

$$\pi_{ikt} = \alpha Profit_{k,t-1} + \beta_k \boldsymbol{T'}_{it-1} + \gamma_k soilmoisture_{it-1} + \eta_k \boldsymbol{V'}_i + \delta_k crop_{it-1} + \omega_k \boldsymbol{X'}_i + \theta_k Year + \tau_k + \varepsilon_{ikt} \quad (2)$$

where α represents impact of previous season's profits. $\boldsymbol{T'}_{it-1}$ is a vector of lagged growing season mean and extreme temperatures, γ_k estimates the crop-specific impact of lagged growing season soil moisture, $\boldsymbol{V'}_i$ is a vector of long-term climate variables, $crop_{it-1}$ represents the previously grown crop and $\boldsymbol{X'}_i$ is a vector of field characteristics including field size, elevation, soil quality, and access to irrigation. Year trends, a crop-specific fixed effect, τ_k, and field by year random effects are also controlled for.

Our yield-weather model reveals crop-specific thresholds for extreme weather. For example, maize and sugar beet yields decline at temperatures below 5 and above 35°C, whereas wheat yields decline at temperatures below 0 and above 20°C. Our preliminary crop choice model shows, unsurprisingly, that profitability positively influences crop choice. Higher mean growing season temperatures positively influence the probability of growing sugar beet and sunflowers, with cooler temperatures indicating a shift to winter wheat and rapeseed. Wetter conditions increase the likelihood of growing maize relative to other crops. We find that small field sizes increase the probability of growing all other commodity crops except for wheat, relative to maize.

Under a climate change scenario with particularly dry conditions (MPI-M-MPI-ESM-LR for RCP 4.5), yields can decline by as much as 20%, indicating significant changes to fields' productivity. There is also a shift in crop choices with a dramatic decrease in probability of planting soybean. The probability of planting sunflower experiences a significant increase as it can withstand extreme temperatures. Simulations for other scenarios including regressions with field productivity variables are still running at this time and are expected to be completed by the time of the conference.

The vulnerability of the agricultural sector to climate change has raised interest on understanding how crop choices adapt under future climate scenarios. Our study benefits from being the first to study field-level farmers' crop choices and yields across Serbia, as well as being one of the largest, high-resolution studies of its type. We find extreme weather thresholds to vary across crops and average as well as extreme temperatures to affect crop choices. Under dry scenarios, yield tend to decrease, and farmers switch away to more tolerant crops. Given the global emphasis on understanding climate change impact on agriculture, we believe our work will generate significant discussion at the AAEA as we present a holistic picture of how climate change affects farmers' current and future cropping decisions through linking variability in weather patterns with the hydrological cycle and changing market conditions.