Water Scarcity in the Serbian Danube:

Agricultural land use change and irrigation

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Climate Change and Agricultural Land Use

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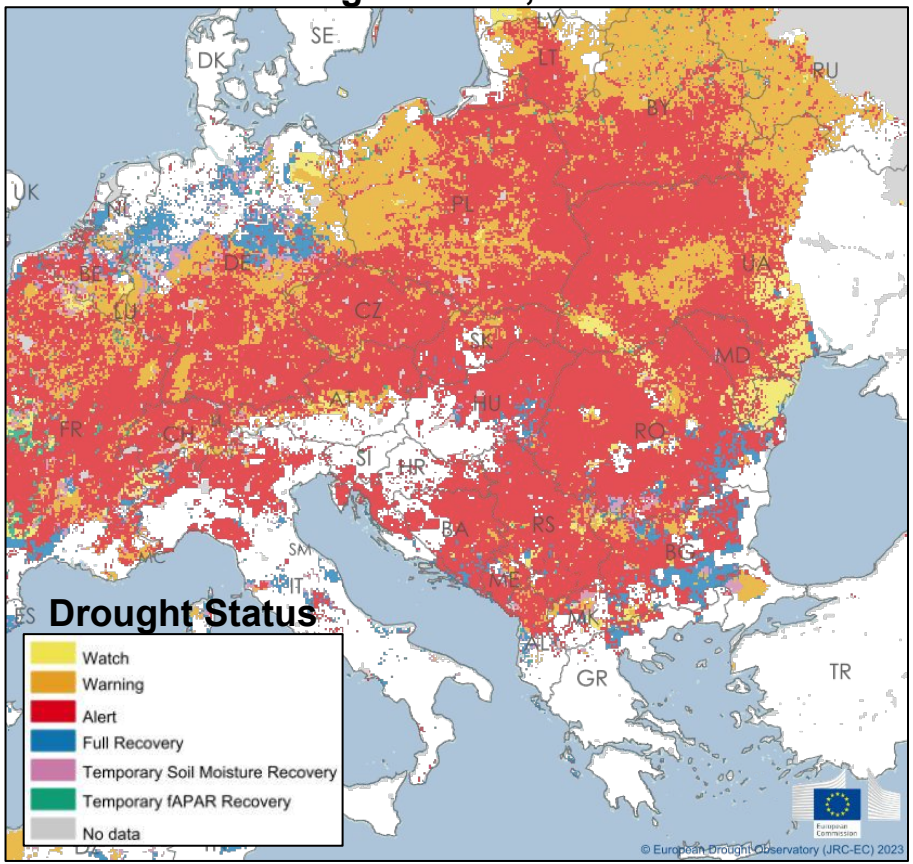
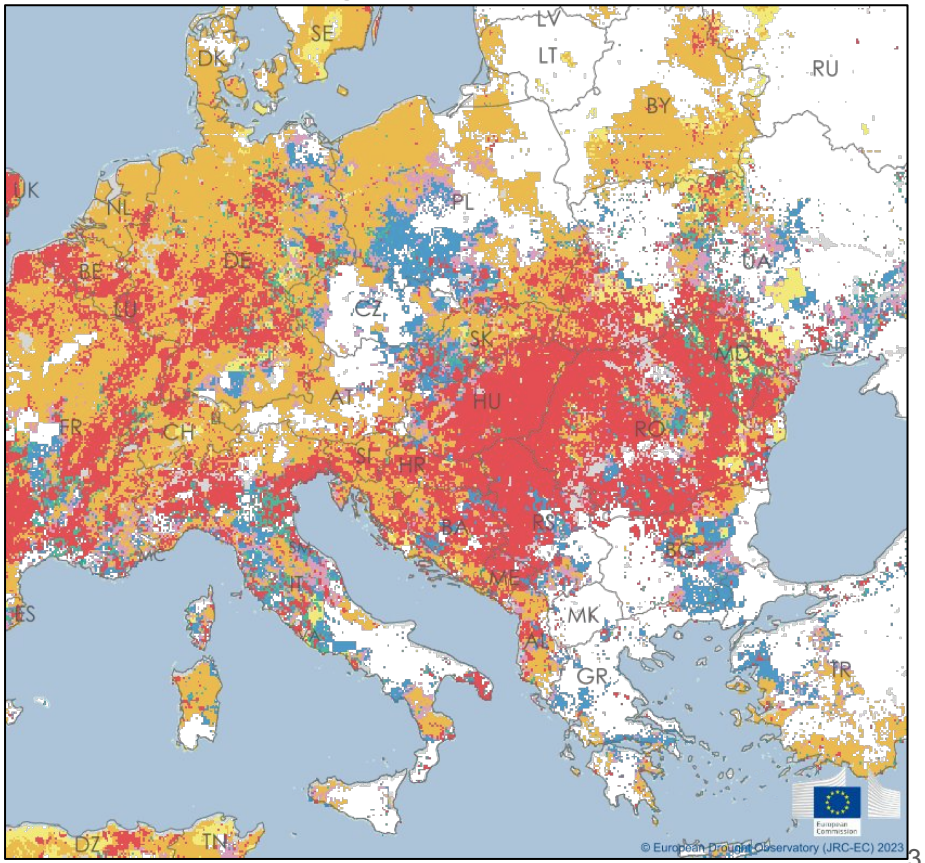
Recurring droughts in the Danube River Basin

August 10-20, 2015



August 10-20, 2022



European Drought Observatory, Combined Drought Indicator v2.2 = *f*(precipitation, soil moisture, Fraction of Absorbed Photosynthetically Active Radiation)

The New York Times

Europe's Rivers, Starved by Drought, Reveal Shipwrecks, Relics and Bombs

August 23, 2022

The Danube River is running so low on water that the wreckage of German warships, sunk in 1944, has resurfaced, posing a danger to local ship traffic.

The Danube's dry riverbed (Banastor, Serbia)

Fedja Grulovic/Reuters

Wreckage of a World War II German warship in the Danube (Prahovo, Serbia)

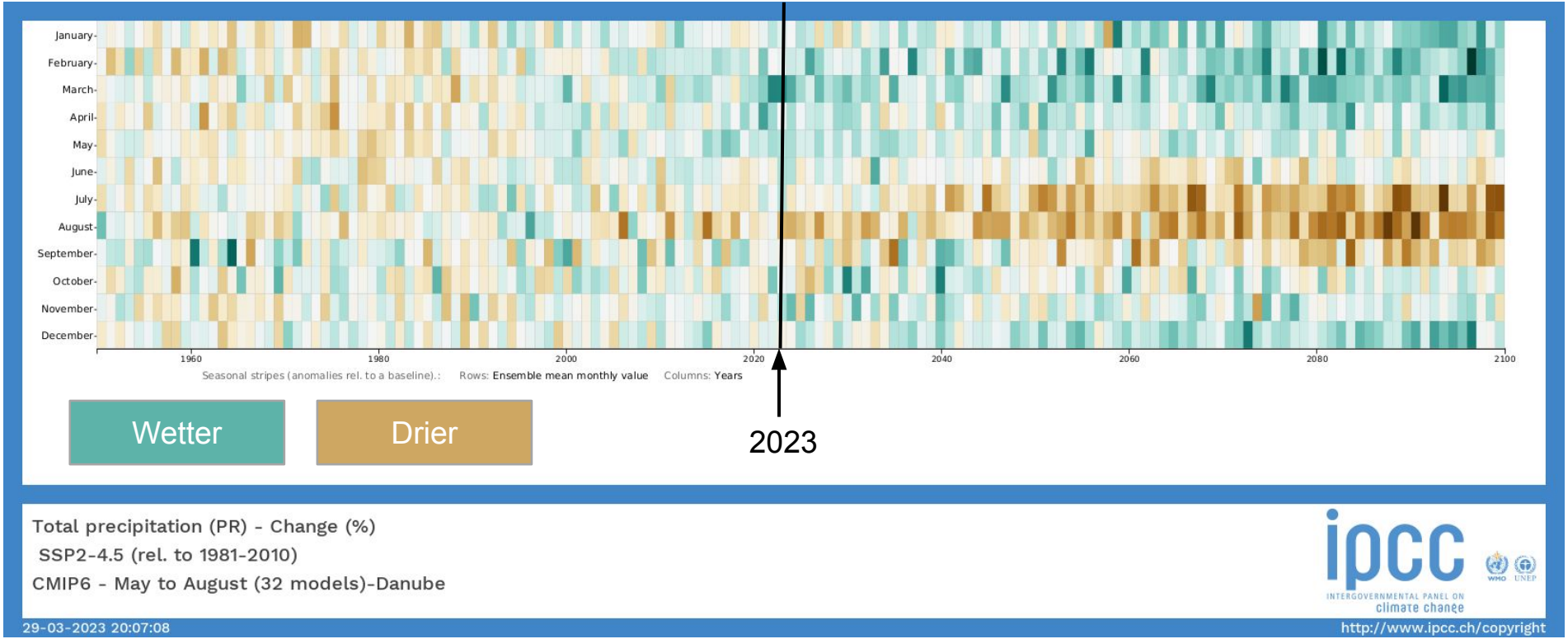
Fedja Grulovic/Reuters

A warmer and **drier** Danube (in the growing season)

Summer precipitation declines of ~15% (2041-2060) compared to 1981-2010 baseline

Equivalent to a loss of ~1.5 in of rain

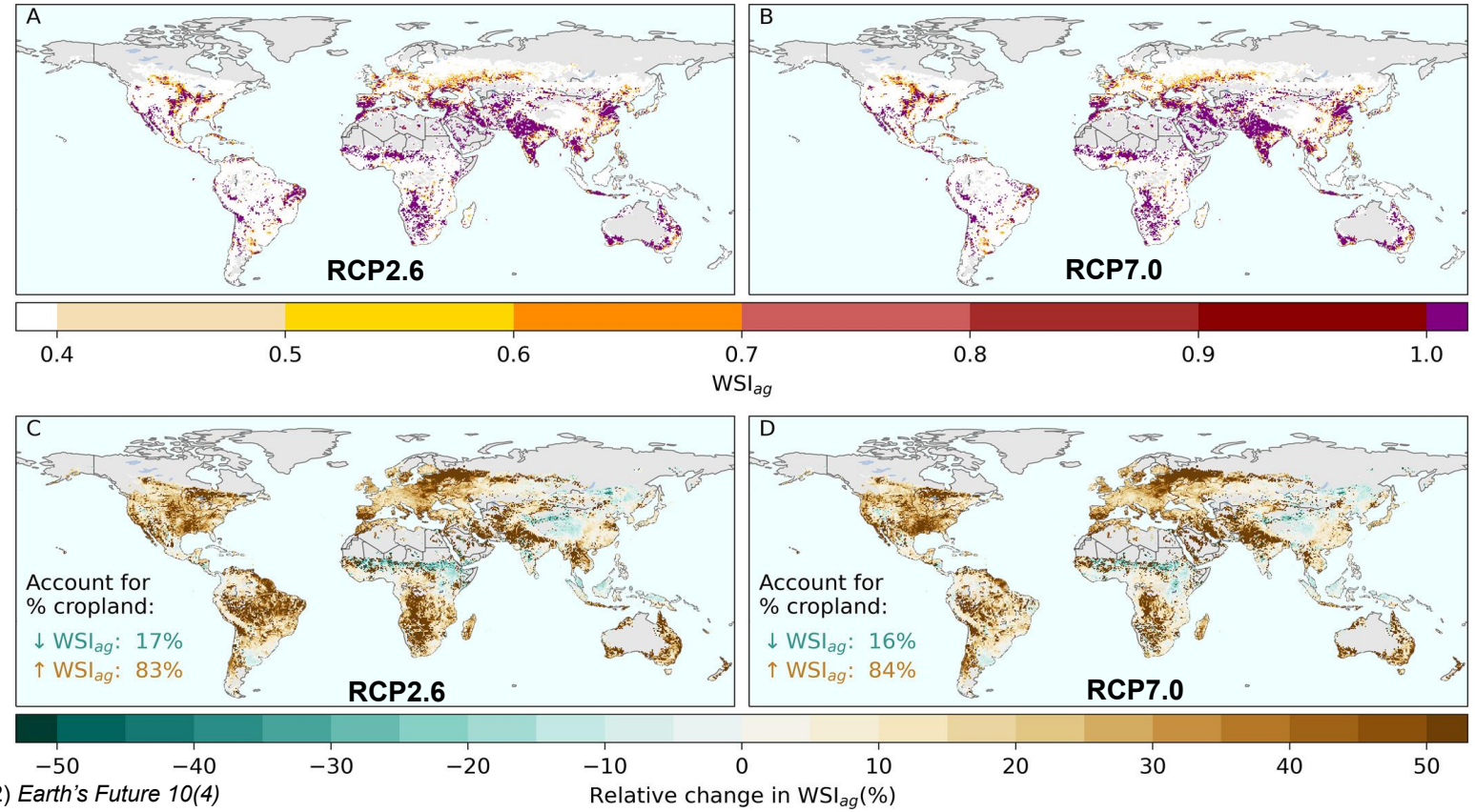
Increase in consecutive dry days



Global water scarcity in major agricultural regions

Intensifying water scarcity will affect 80% of global cropland by 2050

Evapotranspiration demand outpaces green water (soil moisture) and blue water (surface and groundwater)



Liu et al. (2022) *Earth's Future 10(4)*

Serbian Agriculture, Water, and Policy

- Agricultural sector:
  - 10% of GDP, employs 21% of population
  - 5 million ha (70-120k ha irrigated)
  - 630,000 farms (most < 10 ha)
  - Maize, wheat, soy, sunflower, sugar beet
  - Complex rotations (3-4 crops)
- EU accession negotiations (2014-ongoing)
  - Changing agricultural policy
  - Access to EU single market
- Danube River Protection Convention
  - Transboundary water management
  - Sustainable use and protection of resources
  - 14/19 countries are full members (incl. Serbia)


Credit: Irrigation Strategy Serbia

Serbian Agriculture and impact of 2022 drought

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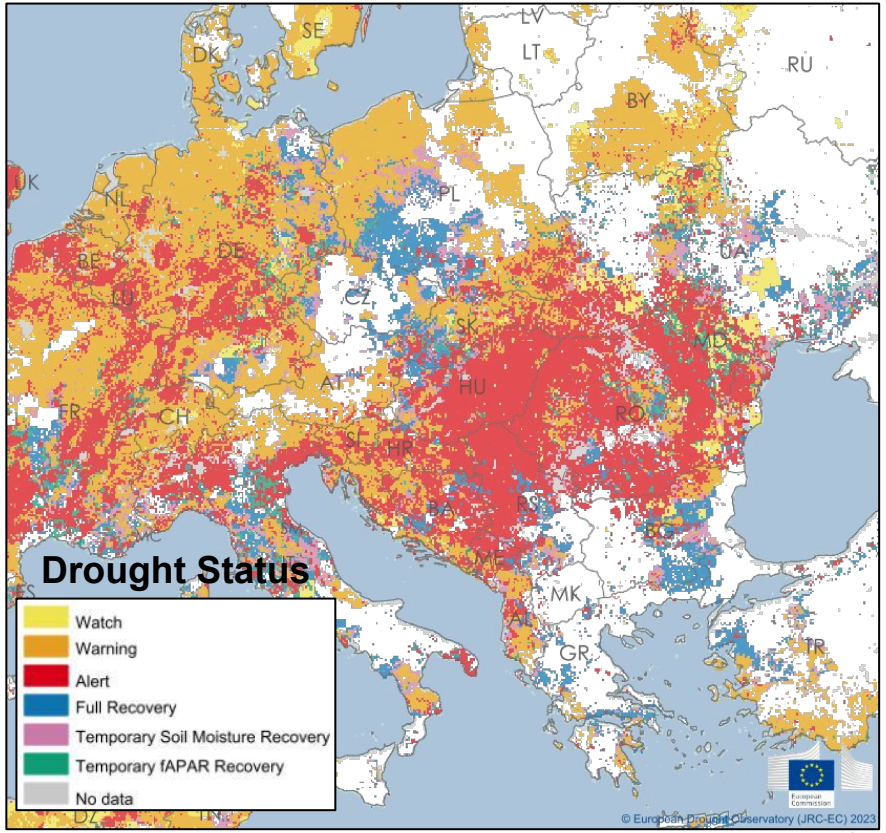
  - Complex rotations (3-4 crops)

- 2022 Production[1] = $1bn USD decline[2]
  - Maize ↓ 25%
  - Soybean ↓ 26%
  - Sugar beet ↓ 21%
  - Wheat ↑ 10% (wet spring)
  - Sunflower ↑ 6%

August 10-20, 2022



[1]Statistical Office of the Republic of Serbia; [2]USDA Foreign Agricultural Service

Land and water management choices in a warmer and drier world

<u>The producer</u>

- What to plant? (Markets, yield, weather)
- When should I plant?
- Should I invest in irrigation?

<u>The landscape</u>

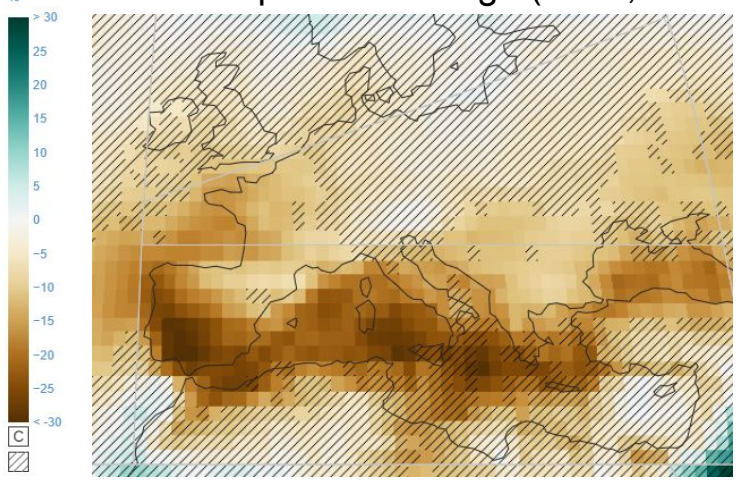
- How do these choices change the landscape?
- How do these choices affect water availability?
- Will this change in a warmer world?

Research Questions

Overall objective: identify the dominant factors driving agricultural land use change in the Serbian Danube, and their relative influence on water availability

1. Shifts in crop rotations?
   - How do rotations change over time?
2. How is water availability and use changing?
   - 1992-present
   - Future: +1.5° C, +2° C
3. How do farmers respond in their decision-making?
   - Market prices
   - Weather
   - Investment in irrigation infrastructure?
4. How will climate change, water availability, and policy changes influence crop rotation and irrigation investment?

Summer Precipitation Change (+2°C, CMIP6)



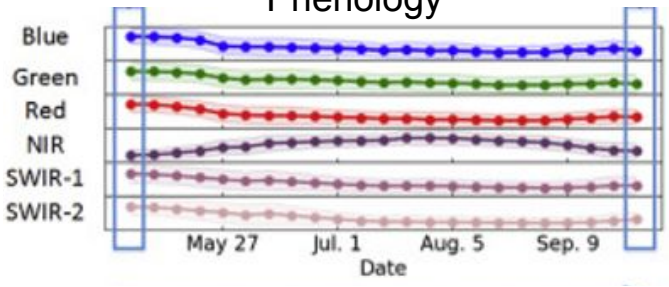
Q1: How do crop rotations change over time?

Objective: *Create annual crop maps from 1992-2022*

Landsat Collection 2

Preprocessing
(e.g., clouds, cloud shadow, etc.)

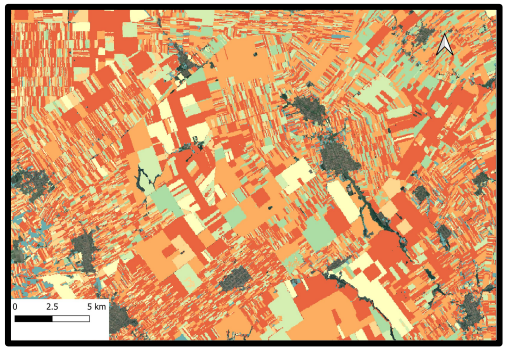
Phenology



Field training data &
crop maps, 2016-2022
(BioSense Institute)

DeepCropMapping[1]
(LSTM) classification

Post-processing
(de-speckle - floodfill)



Crop rotation maps
(annual, 6 key crops)

[1]Xu, J., et al. (2020) *Remote Sensing of Environment*

Q1: How do crop rotations change over time?

2018 preliminary classification (Vojvodina Province, Serbia)

Reference Map (BioSense, 2018)

DeepCropMapping (Landsat 8)

Legend

- Maize
- Wheat and Barley
- Soybean
- Sugar beet
- Sunflower
- Oilseed rape
- Other {Clover, Vegetables, Orchards, Vineyards, Pasture}
- Non-agricultural land {Urban, Water bodies, etc.}

Q1: How do crop rotations change over time?

Ongoing and future work

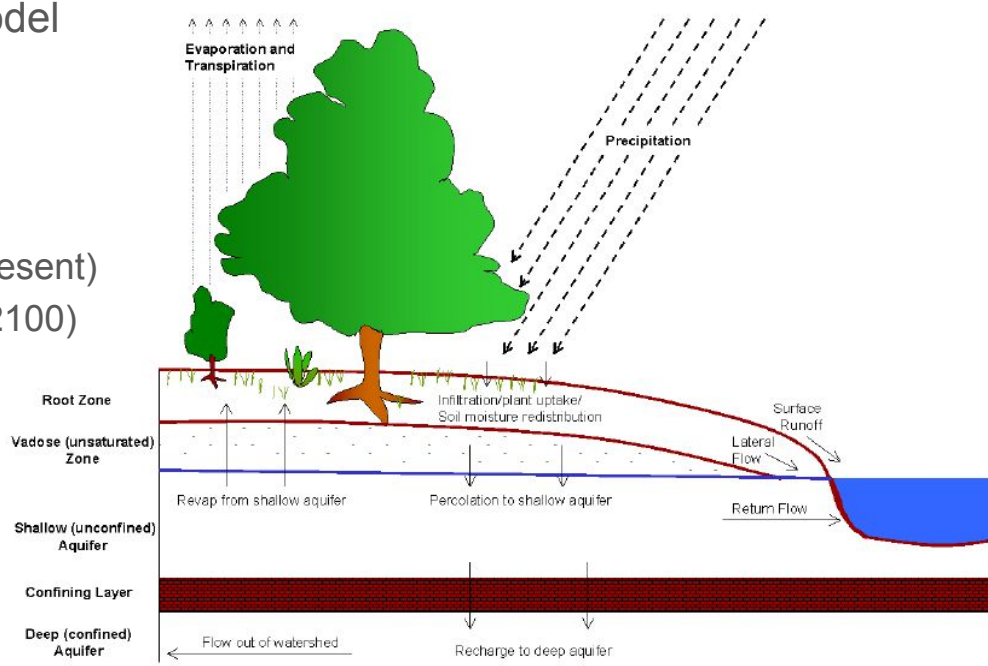
- Classifier transferability
  - Annual maps to 1992
- Improved phenology representation
  - Not restricted to plant/harvest dates that vary annually and spatially
- Improved post-processing
  - Segmentation algorithms
  - SegmentAnything (Meta)

DeepCropMapping (Landsat 8)

Q2: How is water availability and water use changing?

Objective: Quantify and map water scarcity from 1992-present, and at + 2°C

- Process-based, distributed hydrological model
  - Water, N, and P cycles
  - Plant growth – yield estimates (EPIC)
- Daily weather time series
  - *Observed:* EU Copernicus E-OBS (1950-present)
  - *Future:* EURO-CORDEX ensemble (1981-2100)
- Agricultural practices
  - Crop rotations (from Q1 crop maps)
  - Irrigation (amount, frequency, source)
- Calibration and uncertainty analysis
  1. Global Runoff Data Centre discharge
  2. Annual country-level crop yield (RS Statistics)
  3. Remotely-sensed ET(?)

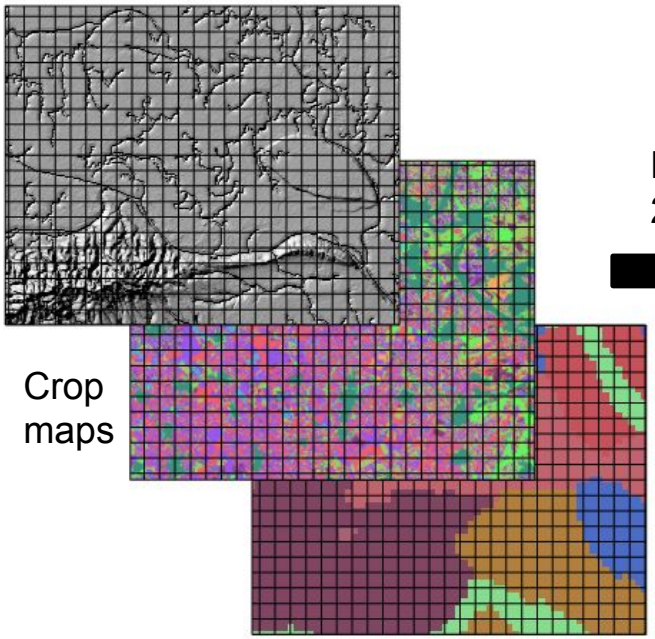


SWAT Soil & Water Assessment Tool

Q2: How is water availability and water use changing?

Model input data, parameterization, uncertainty

25m DEM

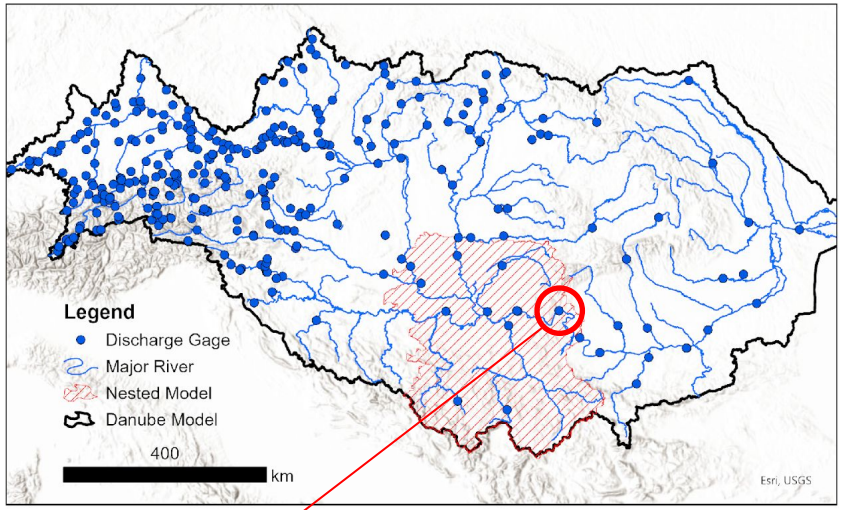


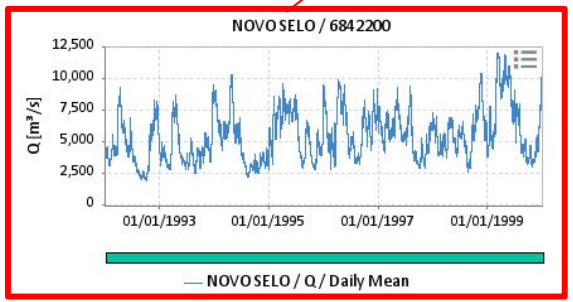
Crop maps

Harmonized World Soil Database

Parameterize 2 km grid cells

Simulate daily water balance at each grid cell (1981-2100)





Calibration and uncertainty analysis

Q2: How is water availability and water use changing?

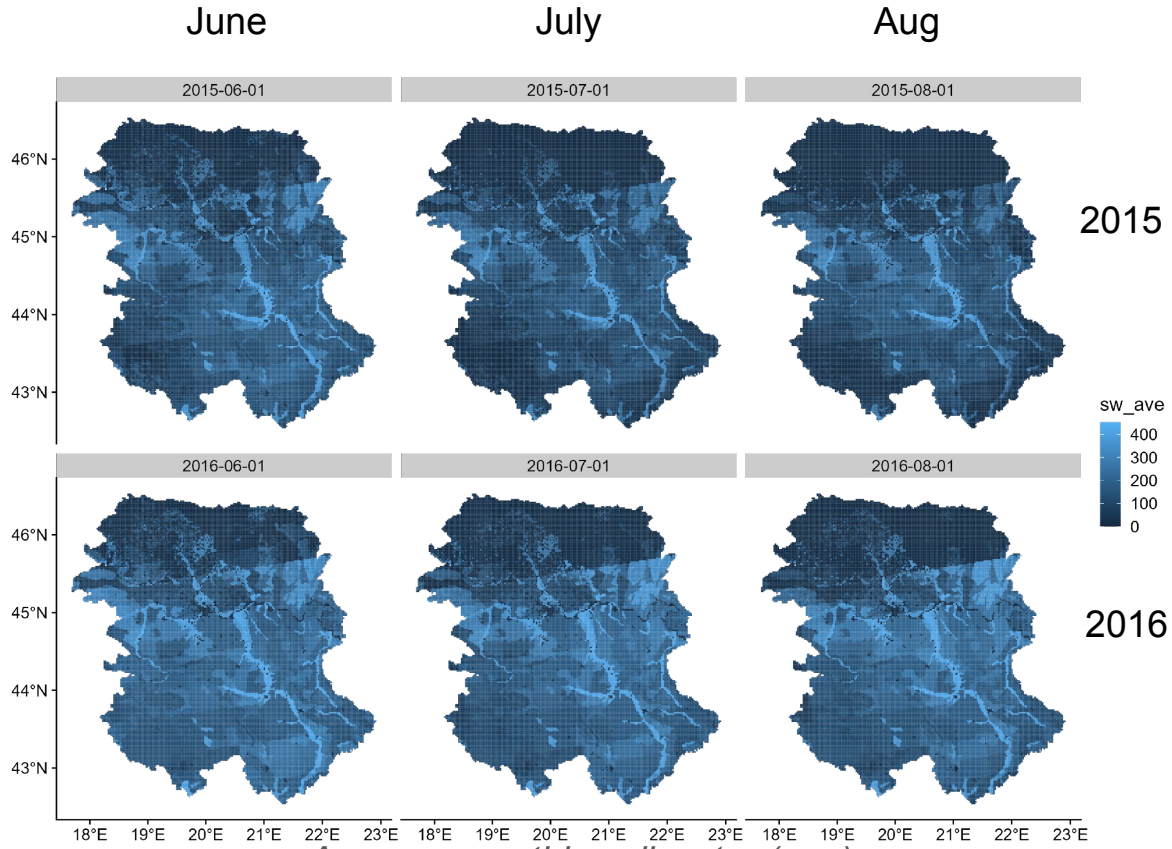
Ongoing and future work

<u>Model evaluation</u>

- Integrate crop rotations
- Calibrate/validate
- Uncertainty analysis

<u>Future climate runs</u>

- EURO-CORDEX regional climate model
- 7 models/ 2 RCPs
- 1981-2100



Average monthly soil water (mm)
Summer 2015-2016

Q3: What climatic, market, and policies influence crop choice and irrigation investment?

Objective: *quantify how land use and irrigation decisions respond to commodity prices, waeather, and socioeconomic trends*

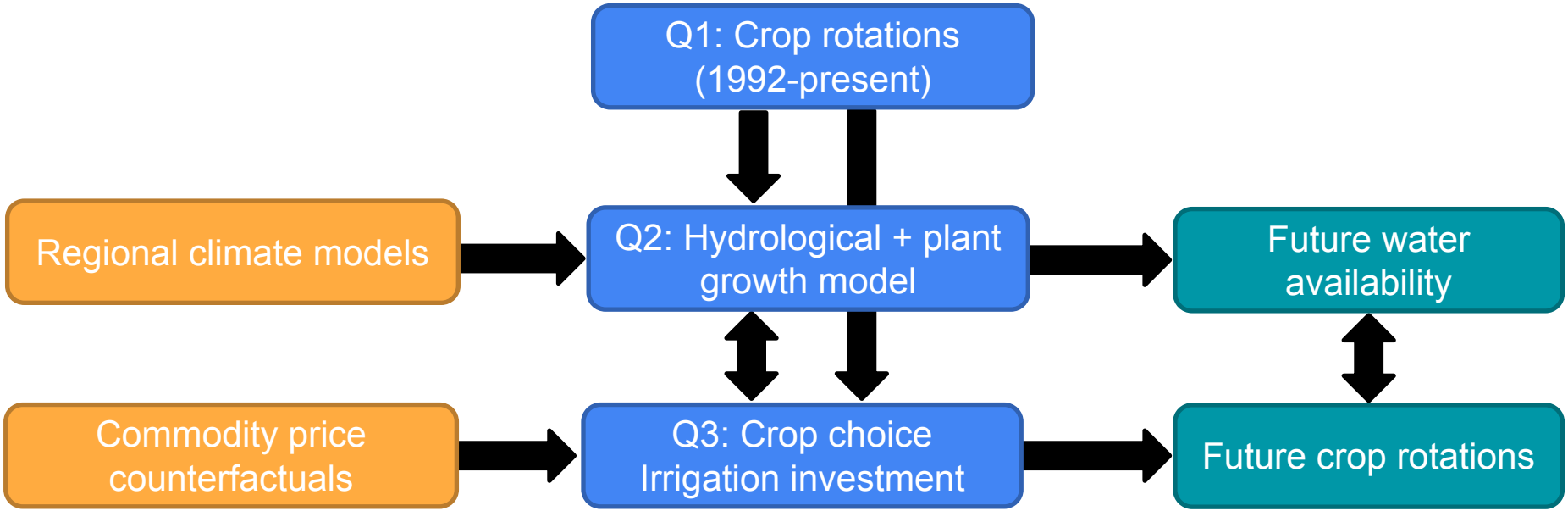
Markov transition matrix:
defines the rotation probabilities between any two crop types

		Year t+1 Crop			
Year t Crop		Maize	Soy	Wheat	Other…..
	Maize				…..
	Soy				…..
	Wheat				…..
	Other…	…..	…..	…..	…..

- Crop specific switching costs: maize → (wheat is less costly than maize) → wheat
- $\hat{p}_m|c_t{=}m$ is the estimated probability of maize (m) in year t+1 IF field was maize in previous year
- Use multivariate regression to generate $\hat{p}_m$ as a function of **prices, planting weather, soil, and water availability**

Q4: How does a warmer and drier Danube affect water availability ↔ cropping systems?

Objective: *quantify future water availability/use and crop rotations in response to climate change*



Significance and Impact

- Forecasts of future water scarcity and agricultural productivity/rotational changes
- Climate change impacts on the agricultural sector
  - Inform policy and decision-making related to public irrigation infrastructure and water use
- Does trade policy exacerbates or alleviate water scarcity issues?
  - EU affects prices in Serbia, which affects planting and water scarcity

Thank You!

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