Modeling wheat yield gaps in European Russia using the SWAT model

Schierhorn, Florian
Faramarzi, Monireh
Prishchepov, Alexander V.
Koch, Friedrich
Müller, Daniel

SWAT conference 2013 | 17 – 19 July
Rising demand for agricultural products

→ **Population**
  - 2.5 billion more by 2070
  - Growing affluence

→ **Diets**
  - Meat
  - Processed food

→ **Bioenergy**
  - Traditional (80%)
  - Modern (20%)
Two options to increase agricultural production

1. **Expansion** of agricultural land
   - Most fertile land already used
   - Further expansion associated with high environmental tradeoffs

2. **Intensification** on existing agricultural land
   - More inputs per unit of land
   - Better technology
Low yields due to yield gap?

Cereal yield

Source: FAOSTAT 2013

- Germany
- Ukraine
- USA
- Russia
Objectives

- Simulation of post-Soviet wheat yields using SWAT [->capturing of inter-anual yield variations]

- Simulation of wheat yield potentials

- Sensitivity analysis of growing period (& PHU) and crop parameters on yield
546 subbasins -> 30
selected for individual calibration
Model setup

- Calibration: 1996-2006 / 3yrs warm-up
- Validation: 1991-1994 / 3yrs warm-up
- Study area size: 4 million km² square kilometers
- Hargreaves method for ET-estimation
- Dominant soil and land use property
- Winter wheat & spring wheat dominant
- Assignment of ONE representative subbasin per province (oblast)
  -> 30 regions to be calibrated indi
Data

• Landuse: Binary cropland map (100 ha)
• Soil: Harmonized World Soil Database (10 km)
• Climate: Daily weather data from Schuol and Abbaspour (2007)
• Wheat yield: ROSSTAT 2012 (provinces)
• Management:
  • Growing period – USDA
  • N fertilizer – ROSSTAT 2012
Calibration, Validation, and scenarios analysis

• Wheat yields were calibrated for each province
• Simulated wheat yields were compared with annual wheat yield data reported at provincial level
• After satisfactory calibration/validation, two scenarios: A) sufficient N fertilizer, B) sufficient N fertilizer + Water were constructed [to access yield potentials]
Crop related parameters were excluded for calibration!
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Calibration and Validation results

Calibration

Validation
Yield gap for sufficient N & Water supply

- Bashkortostan
- Belgorod
- Bryansk
- Chuvash
- Kirov
- Krasnodar
- Kursk
- Lipetsk
- MariEl
- Mordovia
- Moscow
- Nizhny
- Oryol
- Penza
- Perm
- Rostov
- Ryazan
- Samara
- Saratov
- Stravropol
- Tambov
- Tatarstan
- Tula
- Udmurtia
- Ulyanovsk
- Volgograd
- Vologda
- Voronezh

**Legend**
- Yield potential for sufficient N & WATER supply
- Yield potential for sufficient N supply
- ▲ Reported

**Graph Details**
- Wheat yield (t/ha)
- Yield gap for sufficient N & Water supply
- YGN & N

**Years**
- 1995
- 2000
- 2005
Average wheat yields, 2001-2006

Average wheat yields reported 2001-2006

- **t/ha**
  - 1.10 - 1.18: 2.44 - 2.53
  - 1.19 - 1.35: 2.54 - 2.94
  - 1.36 - 1.48: 2.95 - 3.15
  - 1.49 - 1.87: 3.16 - 4.31
  - 1.88 - 2.16: 4.31 - 5.00

Regions:
- European Russia
- Ukraine

Note: The map shows the average wheat yields in t/ha across various regions in Russia for the period 2001-2006.
Yield gap for sufficient N supply

Average yield gap for sufficient N supply, 2001-2006

- **1.16 - 1.43**
- **1.44 - 1.75**
- **1.76 - 1.80**
- **1.81 - 1.97**
- **1.98 - 2.17**
- **2.18 - 2.31**
- **2.32 - 2.37**
- **2.38 - 2.52**
- **2.53 - 2.82**
- **2.83 - 3.03**
- **3.04 - 3.03**

Spring wheat

[Map showing yield gaps in different regions of Russia and Ukraine, with color coding for yield ranges.]
Yield gap for sufficient N supply & water supply

Average yield gap for sufficient N & Water supply, 2001-2006

Yield gap for entire European Russia:

2.1 t/ha -> under sufficient N supply

3.2 t/ha -> under sufficient N & Water supply
Yield sensitivity to growing period

Bashkortostan  Chuvash  Kirov  MariEl
Mordovia  Nizhny  Penza  Perm
Samara  Saratov  Tatarstan  Udmurtia
Ulyanovsk  Volgograd  Vologda

95PPU of simulated yield, average growing period
95PPU of simulated yield, short growing period
95PPU of simulated yield, long growing period
Yield sensitivity to crop parameter

- **Mordovia**
- **Nizhny**
- **Penza**
- **Samara**
- **Saratov**
- **Tatarstan**
- **Ulyanovsk**
- **Volgograd**

Reported

Spring wheat yield (t/ha)

95PPU of simulated yield for sufficient N & Water supply, Variation of crop parameters

95PPU of simulated yield for sufficient N & Water supply, SWAT default crop parameters

Reported

95PPU of simulated yield for sufficient N & Water supply, SWAT default crop parameters

Reported
Conclusion

• Russia has large potential to increase crop yields
• SWAT crop growth module reproduces accurate yields despite the large scale & data scarcity
• Yield gaps are heterogeneously distributed
• Information on crop characteristics (PHU in particular) are essential for accurate yield gap estimations
Thank you very much.

Contact:
Florian Schierhorn
(schierhorn@iamo.de)

www.iamo.de
Calibration and Validation results