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Land System Change Group

Leibniz Institute of Agricultural Development
in Central and Eastern Europe

Economic and natural potentials of agricultural production and carbon trade-offs in Kazakhstan, Ukraine, and Russia – EPIKUR
Leibniz Foundation

Global food security and the grain markets of Russia, Ukraine and Kazakhstan - GERUKA
German Federal Ministry of Food, Agriculture and Consumer Protection -BMELV

GERUKA

<u>Scale:</u>

- Across countries at province level, 1990-2012
- Detailed case studies for three provinces *(Rjazan -Russia, Lviv –Ukraine, Kostanai –Kazakhstan), 1990-2000-2012*

Modeling crop yields and yield gaps in Russia, Ukraine and Kazakhstan considering land use dynamics and climate change

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Introduction

- Increasing global agricultural production is a key challenge in the 21[th] century due to population growth, changing diets and increasing demand for bioenergy.
- **Russia, Ukraine and Kazakhstan (RUK)** possess great potentials to increase agricultural production due to large areas of abandoned cropland (Fig. 1), low crop yields (Fig 2) and abundant fertile soils (Fig. 3).
- We quantified wheat yield potentials for European Russia using the process-oriented Soil and Water Assessment Tool (SWAT, Arnold et al. 1998).
- We aim to assess yield gaps for the whole region and quantify the impact of climate and land use change.

Material and Methods

- SWAT (Fig. 5) was configured with ASTER (DEM) and HWSD (Soil) -data, a binary cropland/non-cropland map (Fig. 4, Schierhorn et al., in review) and meteorological inputs from CRU (Mitchell and Jones, 2005).
- We calibrated and validated the model with official crop yield statistic and the sensitivity analysis tool: SWAT-CUP (Abbaspour et.al. 2004).
- SWAT uses the modified erosion productivity impact calculator (EPIC) for crop growth modelling, considering leaf area development and light interception (Williams, 1990).
- We simulated annual yield potentials for 1995 to 2006 under sufficient N-fertilizer supply and rainfed conditions (S1), and under sufficient N without water limitation (S2).

Results

- Average winter wheat yield potentials are 4.79 t/ha under S1 and of 5.76 t/ha under S2 (Fig. 6); yield potentials of spring wheat are 3.77 t/ha (S1) and of 4.95 t/ha (S2).
- Average yield gaps for winter and spring wheat are 51% (S1) and 60% (S2) of potential yield.
- The average yield gap for winter wheat is 52% (S1) and 43% (S2); yield gaps for spring wheat are 58% in S1 and 68% in S2.
- Water stress crucially limits wheat yields; irrigation therefore may significantly increase yield potentials.

Perspective

- We aim to produce a comprehensive model covering the whole RUK region with the ultimate goal to quantify agricultural production potentials for the entire RUK region under consideration of climate change and recultivation scenarios.
- We plan to validate with detailed models that help reducing overall uncertainties; multi-objective calibration is planed including hydrology (discharge) and crop yields.
- We will investigate water availability and apply realistic irrigation scenarios; this is crucial to assess climate change impacts on agricultural productivity.
- We will use expert opinions and farm-level data collected during field visits in 2014/2015.

References

Abbaspour KC, Johnson CA, van Genuchten MT. (2004). Estimating Uncertainty Flow and Transport Parameters Using a Sequential Uncertainty Fitting Procedure. *VADOSE ZONE J.* 3: 1340-1352.

Alcamo, J., Dronin, N., et al. (2007). A new assessment of climate change impacts on food production shortfalls and water availability in Russia. Global Environmental Change 17: 429-444.

Arnold JG, Srinivasan RS, Muttiah JR. (1998). Large area hydrologic modeling and assessment, Part I: Model development. *JAWRA*; 34:73-89.

Williams, J.R. (1990). The Erosion-Productivity Impact Calculator (EPIC) Model: A Case History. Philosophical Transactions of the Royal Society of London 329: 421-428.

Schierhorn, F., Müller, D. et al. (in review). (*Global Biogeochemical Cycles*).

Large production potentials in Eastern Europe and Central Asia

Fig. 1: About **40 million ha** (~33%) of former agricultural land was abandoned since 1990; abandoned land is in different stages of successional vegetation.

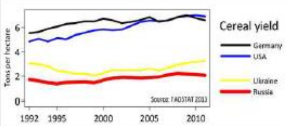


Fig. 2: Cereal yields in Russia and Ukraine are **low and increased only modestly since the early 1990s.**

Fig. 3: The highly fertile **Chernozem (Black Earth)** area covers 2.05 million km²

Source: Harmonized World Soil Database

Cropland distribution and SWAT framework

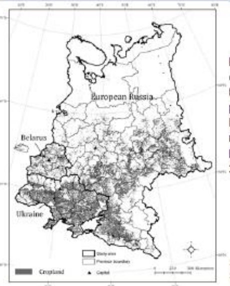


Fig. 4: Contemporary cropland concentrates in the Chernozem Belt; at present, **European Russia has about 51 million ha** of arable land and **Ukraine about 31 million ha.**

Source: Schierhorn et.al. (in review)

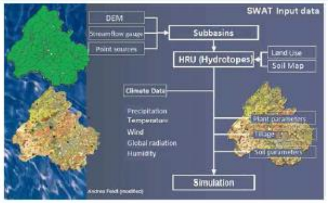
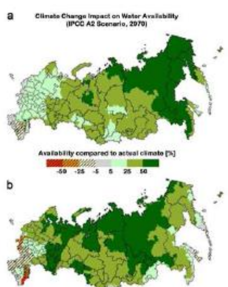


Fig. 5: **SWAT** is a spatially explicit catchment model covering hydrology, nutrient cycles, sedimentation, plant growth, pesticides, and artificial structures.

Climate change



Source: Alcamo et. al., 2007 based on HADCM 3 (a) and ECHAM (b)

Fig. 8: **Climate change** is likely to strongly affect water availability; models predict increases in dry regions of RUK but decreases in highly productive Chernozem areas; temperature is expected to rise by 1-5 °C. These changes may critical impacts on agricultural productivity and compromise production potentials.

Yield gaps and production potential

Yield gaps under optimal N + water supply (S2)

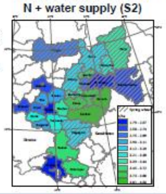


Fig. 6: Average **yield gaps** account for 39-62% of the potentials and were mainly driven by high climate volatility; drought risks reduce investments in agricultural inputs.

		Cropland in 2030		
		80 Mha	95 Mha	110 Mha
Yields in 2030	2009 yields	182	217	251
	70% of yield potential	240	285	330
	Yield potential	360	428	495

Fig. 7: **Wheat production potential** in European Russia under scenarios of recultivation (columns) and yield gap closure (rows).

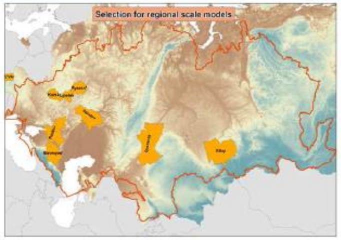


Fig.9: We have selected **nine in-depth regions** based on a stratification along agro-climatic and socio-economic conditions; ultimately, we will produce yield gap estimates with SWAT for the whole RUK region.

Trajectories and determinants of agricultural land-use change in the former Virgin Lands area of Kazakhstan

MARTIN-LUTHER-UNIVERSITÄT HALLE-WITTENBERG

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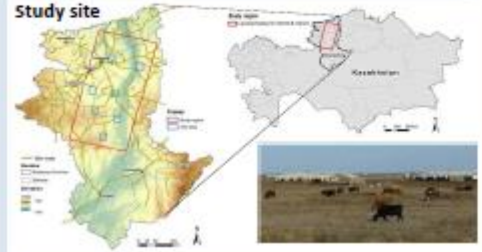
Background

In the course of the Soviet Virgin Lands Campaign ~ 45 million hectares of Eurasian steppe grasslands were converted into croplands between 1954 and 1963, of which over 19 million hectares were ploughed up in Northern Kazakhstan. The breakdown of the Soviet Union in 1991 and socio-economic and institutional changes resulted in contraction of agricultural land-use. However, there is still high uncertainty about the actual trajectories, the patterns and the drivers of agricultural land-use change (LUC), especially in former Virgin Lands area of Kazakhstan.

Research questions

1. How can we accurately map agricultural land-use change (LUC) in steppe regions with **remote sensing** techniques?
2. What are the **spatial patterns and trajectories of agricultural LUC** in the study area (Kostanay province) since the beginning of the Virgin Lands Campaign (VLC)?
3. What are the socio-economic and environmental **determinants** of the spatial pattern of agricultural LUC in the study area?

Study site



Part I: Mapping agricultural LUC

BACKGROUND:

- No reliable (spatially explicit) data on land-use are available for Kazakhstan
- Challenge to map accurately managed grasslands in steppe landscapes with satellite images (e.g. Gong et al. 2013)

OBJECTIVES:

- Producing LUC map for Soviet (pre-1954 - 1990) and post-Soviet period (1990 - 2010)

METHODS:

- Utilizing archival records from pre-1954 to 1990 and Landsat TM & ETM+ imagery for three time-steps (circa 1990 - 2000 - 2010)
- Change detection using multi-temporal composite images with Support Vector Machines
- Classification accuracy assessment (visiting validation sites, completed October 2013)

Part II: Identifying determinants of LUC

BACKGROUND:

- Market-oriented agricultural LUC is driven by economic decisions of rational behaviour of agricultural agents to maximize their profits
- Underlying drivers (e.g., institutional & environmental settings, crop prices) impact the decison of agricultural agents about proximate drivers of agricultural LUC (e.g., abandonment of environmentally marginal agricultural areas)

OBJECTIVES:

- Identifying the underlying and proximate drivers of agricultural LUC pattern using participatory interviews with agricultural experts and farmers and detailed socio-economic & biophysical data
- Developing spatially explicit models to explain the pattern of agricultural LUC

METHODS:

- Spatially explicit logistic model explaining the patterns of agricultural LUC (*1-converted, 0-active cropland*) for three trajectories (*converted to grasslands by 2000 and stay as grasslands by 2010 (1), converted to grasslands only by 2010 (2), converted to grasslands by 2000, but plowed again by 2010 (3)*) with independent variables (*e.g. elevation; soil; distance to roads, railway & settlements; yield & livestock numbers*)

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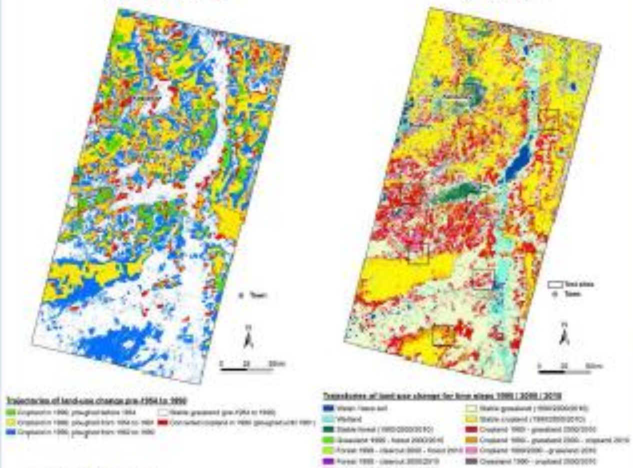
Results of Part I

Pre-1954 - 1990 | 1990- 2010



Acreages of cropland [ha]

	pre-1954	1954 -1961	total by 1961
Cropland area	666,179	1,672,020	2,038,201
of which used by 1990	544,182	1,290,828	1,834,807
Share	73.8%	75.7%	75.0%

	2000		2010				
	Cropland	Converted	Cropland (stable)	Recultivated	Newly converted	Old converted	Total converted
Cropland by 1990	1,793,886	1,292,829	1,348,720	830,337	244,956	962,272	1,207,228
Share	58.1%	41.9%	50.2%	30.7%	7.8%	31.2%	39.2%

Note: 'Grassland' class includes both managed and non-managed grasslands

Assumptions for Part II

Hypothesized underlying drivers:
Socio-economic shock after 1990, population outmigration, crop prices, land-use policies

Hypothesized proximate determinants of agricultural LUC

Covariates	Conversion of cropland to grassland	Plowing again of once converted croplands to grasslands
Soil quality	-	+
Crop yields	-	+
Distance from roads, railways & settlements, grain storage	+	-
Population in the nearest settlement	-	-

Discussion

We observed widespread cropland conversion into grasslands during the first (1990-2000) and the second decade after the collapse of the Soviet Union. Recultivation of once converted croplands into grasslands was common as well from 2000 to 2010.

Post-Soviet socio-economic shock caused drastic decline of livestock from 1990-2000 and decreased the agricultural intensity on grasslands. Recent increase of GDP in Kazakstan (increase of meat consumption), and competition of land-use (wheat production), stimulates increase of livestock numbers and thus agricultural intensification on grasslands. Knowing spatial socio-economic and biophysical determinants of agricultural LUC in steppe region would allow developing plausible trade-offs between different agricultural land-uses and environmental opportunities.