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AGRICULTURAL CHANGE IN THE RUSSIAN GRAIN BELT: A CASE STUDY OF SAMARA OBLAST

ABSTRACT. Change in agricultural land use in Samara Oblast is analyzed on the basis of agricultural statistics, field observations, and satellite imagery. Besides the general decline in animal husbandry, three drivers of spatial change are uncovered – accessibility to the major urban areas, natural setting, and ethnic mix. Land surface phenology metrics are in line with these drivers. In particular, satellite imagery confirms the large amount of fallowed land in Samara. Overall, land abandonment reached its peak in the late 1990s, and was subsequently reversed but the amount of land used in crop farming has not reached the 1990 level. Spatial differentiation is also analyzed across three types of farms – former collective and state farms, household farms, and registered family businesses.

KEY WORDS: agriculture, land use, spatial change, land abandonment, field observations, satellite imagery

INTRODUCTION

Agricultural land use in Russia is undergoing profound changes. These changes arise from the combined effects of introducing capitalism and ongoing rural depopulation. As previous work has shown, in European Russia rural population density is an effective predictor of agricultural productivity [Ioffe et al. 2004, Ioffe 2005]. However, population density itself is under the influence of such factors as the harshness of rural environment (as characterized by the variability of temperature and moisture regimes) and the accessibility of major urban centers [Nefedova 2003].

Kazakhstan, Russia, and Ukraine are often mentioned as the countries with the world's greatest unrealized food production potential [Fay and Patel 2008]. There is a significant gap between potential (i.e., based on natural soil fertility) and actual yields in these countries. This gap is likely to offset the potential yield increase due to climate change [Olesen and Bindi 2002]. Current inefficiencies will need to be addressed to realize the actual yield increase. Some argue that agricultural land transition is one process that needs to occur to improve productivity and efficiency [Lerman and Shagaida 2007]. Potential gains due to projected climate change could be offset by increases in the frequency or shifts in the seasonality of extreme weather (e.g., droughts, [Dronin and Kirilenko 2011]).

In this paper, we will highlight agricultural land use change in Samara Oblast, a region situated within Russia's black-soil (Chernozem) grain belt. We visited this region in the summer of 2010 and performed extensive interviews with district administrators, farm managers and other members of the population. Remote sensing was used to advance our understanding of ongoing agricultural changes in the region over the past ten years.

In what follows, we will focus on the peculiarities of the case study region, methods used to evaluate land use change, and on principal results emphasizing the drivers of spatial differentiation of agricultural land use.

THE CASE STUDY REGION

Samara oblast (53,600 km^2) is located in the middle of the Russian grain belt, in the central Volga River basin in southern Russia bordering northern Kazakhstan (Fig. 1). We chose Samara because the oblast is representative of a) European Russia's south, a macro-region with high natural soil fertility and with only moderate (not drastic) rural depopulation, and b) quite a few Russian regions (north and south) whose regional capitals are very large (close to or over one million people). This second characteristic generates a suburb-periphery land use intensity and productivity gradient within the oblast.

The cities of Samara and Togliatti are the oblast's largest cities with 1.1 million and 720 thousand residents, respectively. In 2010, Samara oblast's population density was 59.2 people/km^2. The rural population density was 11.5 people/km^2. Ethnic Russians dominate Samara's population (83.6%); Chuvash (6%) and Tatars (4.3%) are the largest minorities. Non-Russians predominantly live in the northern areas of Samara oblast. The oblast consists of 27 lower level administrative units (rayons) comparable to counties in the United States.

The oblast is located across the ecotone of forest steppe, with patches of broadleaf forests interspersed with steppe in the north; regular steppe in the middle; and dry steppe in the south. There are about three million hectares of arable land in the region; the main crops are grain, sunflower, sugar beets, and potatoes. According to official statistics, agricultural land in Samara occupies 76% of the territory, with 58% of the territory classified as arable land [Agriculture Samara 2008]. In general, the natural conditions are favorable for agriculture, but despite the frequent droughts that affect the southern part of the oblast, there is limited irrigation. Land abandonment in this area was moderate compared to other oblasts

Fig. 1. Overview of estimated croplands in the region in the year 2000. Samara oblast is located in the middle of the Russian grain belt. The cropland dataset is from Ramankutty et al. [2008] and has a spatial resolution of 0.05° lat/lon

in Russia; about 69% of the area cultivated in 1990 was still cultivated in 2006. Other regions, such as Kostroma oblast, situated farther upstream (along the Volga River), experienced widespread land abandonment; only 55% of the 1990 cultivated area was still cultivated in 2006.

Grain production reveals strong inter-annual variability. In 2009, a third of the crop production was lost in Samara; in the widespread and extreme drought of 2010, this area lost about 40%. While the agricultural potential for the southern rayons is lowest as a result of frequent droughts, nearly 75% of the land area is plowed. Grain yields in these rayons are low and unstable; agriculture is risky, especially now that the number of cattle on large farms drastically declined from 1012 thousand in 1990 to 212 thousand in 2009 [Agriculture Samara, 2004, s.224, 2009 s.100–101].

Russian farmers employ a variety of crop-rotation schemes. In this area, the farmers previously used a seven-year rotation which typically included only one year of fallow and a variety of grain crops in the remaining six years. The fallow year is used to increase subsurface moisture in periods when there is no drought. Farm managers in Samara indicated that the crop rotation schedules are changing from a seven-year crop cycle focused on grain production to a three-year crop cycle focused on the production of sunflower. The new rotation schedule is fallow-grain-sunflower, which ensures a higher profit margin compared with grain alone. The number of cropped years gives an indication of the type of crop cycle that is applied. Crop cycles that include sunflower see increased numbers of fallow years compared to grain based crop cycles. In addition, drier areas are predicted to reveal more fallow years either due to decisions by farm managers or as a result of ongoing droughts. According to farm managers interviewed, far southern Samara tends to experience agricultural drought about half the time.

DATA AND METHODS

1. Field data collection

During a field trip in May 2010 we collected official statistical yearbook data and updated lower level rayon data collected previously [Nefedova 2005, Samara oblast' 2006, Ioffe et al. 2006, Pallot and Nefedova 2007]. We visited typical settlements and enterprises in four selected ***rayons*** (Kinel-Cherkassky, Pokhvistnevsky, Bolshechernigovsky and Pestravsky) within the study region and interviewed rural administration heads, farm managers, and the local population. The four selected rayons are located in east central and far southern Samara. We conducted twenty five loosely structured interviews in four different rayons. Each interview lasted between 30 to 90 minutes. The interviews were typically attended by one to five respondents. We aimed at interviewing a large cross section of people with agricultural interest within Samara. Among the experts we interviewed were Samara's Ministers of Economics and of Agriculture and the head of Samara's Land Use Committee. In addition, we spoke with one local agronomist and heads of one agricultural company (Simko) and four agricultural cooperatives. We spoke with nine different rayon and city administrators, several registered independent farmers as well as household farmers and one owner of a private greenhouse with 4000 tomato plants. We also spoke with the owners of a sausage factory with sixty employees located in a rural Tatar village. Among the farmers and administrators interviewed, there were people from Baskhir, Tatar, and Chuvash ethnicities. The information collected during this fieldwork period provides a largely improved understanding of the economic and rural social situation [Ioffe et al. 2011]. We asked every participant questions with respect to population dynamics, unemployment, subsidies and taxes, and their perceptions of drought and climate change. When appropriate, we also asked to see farms and crops and asked about crop varieties and rotation schemes.

2. Landsat Data

The series of Landsat satellites has measured the Earth's changing land surface since the launch of Landsat 1 in 1972. During the study period the United States Geological Survey (USGS) operated Landsat 5 equipped with the Thematic Mapper (TM) sensor and Landsat 7 with the Enhanced Thematic Mapper Plus (ETM+). Both satellites have a 16-day repeat time and provide multispectral imagery with a spatial resolution of 30m. All Landsat data held by USGS are freely available. Samara oblast is almost entirely covered by four Landsat tiles (WRS-2 P170R23, P169R22, P169R23 and P169R24, Table 1). We collected Landsat TM/ETM+ images for each tile between 2006 and 2010. Each tile was represented by images during the peak of the growing season and at least one shoulder season, with a focus on the fall as much as possible to enable capture of winter wheat growth (Table 1). All images where atmospherically corrected with the ENVI FLAASH routine. FLAASH is a first-principles atmospheric correction tool that corrects wavelengths in the visible through near-infrared and shortwave infrared regions and incorporates the MODTRAN4 radiation transfer code. After correction all available bands, except the thermal band, were stacked into one file per tile. We applied maximum likelihood classification with suitable training samples identified using Google Earth. We validated the results using validation samples identified using Google Earth, and supplemented by field photographs collected at the time of the interviews.

3. MODIS Data

The Moderate Resolution Imaging Spectroradiometer (MODIS) provides near-daily repeat coverage of the earth's surface since 2000 with 36 spectral bands and a swath width of approximately 2330 km. Seven bands are specifically designed for terrestrial remote sensing with a spatial resolution of 250 m (bands 1–2) and 500 m (bands 3–7). Each MODIS swath is divided into 10 by 10 degree tiles that are numbered vertically and horizontally. For this study we selected two MODIS products: 1) the Nadir BRDF-Adjusted Reflectance (NBAR) data set with a spatial resolution of 500 m (MCD43A4v5) and 2) the Land Surface Temperature (LST)/ Emissivity data with a spatial resolution of 1000m (MOD11A2v5) covering the tiles h20v03 and h21v03. The NBAR product is created with the use of bidirectional reflectance distribution functions which model reflectance to a nadir view [Lucht et al. 2000, Schaaf et al. 2002]. The sensors are operated by NASA on two satellites, Terra and Aqua, which have late morning and early afternoon daytime passes, respectively. These data products are freely available online.

We downloaded all available images between January 2002 and December 2009. We calculated the Normalized Difference Vegetation Index (NDVI) using the NBAR dataset. NDVI is a commonly used vegetation index, computed as (NIR – red)/(NIR + red) [Tucker 1979]. NDVI is calculated using the near infrared (841 to 876 nm) and red (620 to 670 nm) reflectance bands and is frequently used to monitor vegetation growth cycles

Table 1. Overview of the Landsat path/row coordinates and dates used to create the land cover classification

169/22	169/23	169/24	170/23
14 Jul 2006	2 Aug 2007	2 Aug 2007	29 Jul 2009
18 Aug 2007	18 Aug 2007	18 Aug 2007	16 Jul 2010
26 Oct 2009	5 Oct 2007	5 Oct 2007	27 Aug 2010
23 Jun 2010	23 Jun 2010	23 Jun 2010	2 Sep 2010
10 Aug 2010	25 Jul 2010	9 Jul 2010	24 May 2011
		10 Aug 2010	

and health [Tucker 1979, Myneni et al. 1997, Morisette et al. 2008]. NDVI is bounded between –1.0 and 1.0 with typical values for vegetation ranging between ~0.2 to ~0.85. Higher values indicate denser vegetation.

We selected the day and night temperature data from the MOD11A2 dataset. We calculated growing degree-days (AGDD) based on the minimum and maximum temperature data as follows:

$$GDD = \frac{\begin{array}{c}\text{Nighttime Temperature} + \\ + \text{Daytime Temperature}\end{array}}{2}. \qquad (1)$$

We accumulated 8-day GDD by simple summation commencing each 1 January when GDD exceeded the base 0°C:

$$AGDD_t = AGDD_{t-1} + \max(GDD_t, 0). \qquad (2)$$

We chose a base of 0°C for the AGDD calculations since this threshold is an often used value in modeling for high-latitude annual crops, such as spring wheat, and for perennial grasslands. Our study region is dominated by perennial grasslands and spring grains. We have successfully applied this method several times before [de Beurs and Henebry 2004, 2005a,b, 2008, 2010]. We applied a quadratic regression model linking AGDD with NDVI to determine simple land surface phenology metrics for each year (Fig. 2). The phenological metrics that we are investigating here are: 1) the timing of the start of the growing season; 2) the thermal time to peak measured in AGDD; 3) the height of the peak of the growing season in NDVI. Higher peaks indicate areas with denser (healthier) vegetation.

We linked the Landsat land cover map with the interannual variability in key phenological parameters derived from two MODIS tiles to derive the percent of cropland per MODIS pixel.

To determine whether a pixel was successfully sown during a particular year, we applied a series of basic decision rules. We aimed to distinguish between cropped pixels and

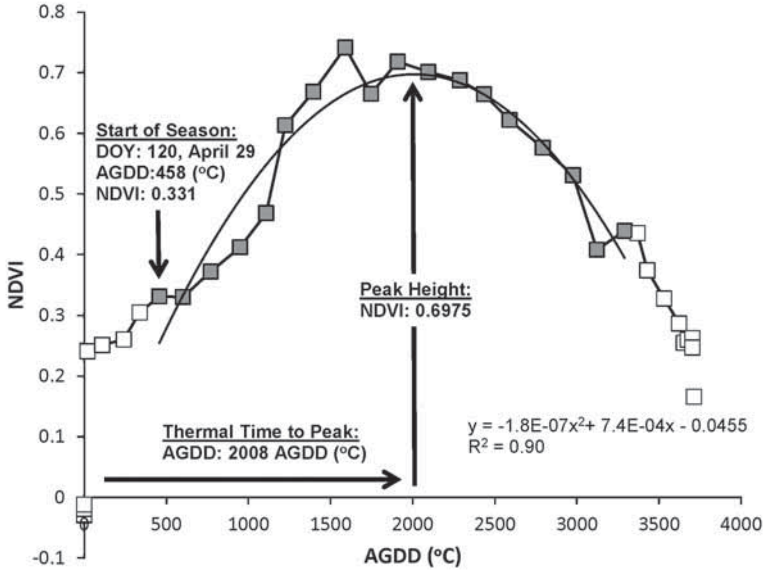

Fig. 2. Land surface phenology model for one grid cell.
In this grid cell the start of the growing season occurred on day 110 (DOY).
The thermal time to peak was 950 growing degree days and the height of the peak was 0.767

fallow pixels within the general class of cropland. The fallow pixels can lay fallow for multiple years and thus have a variety of vegetation types growing on them. However, the fallow pixels must have at least been cropped once during our study period as identified above to be counted as cropland. The phenology models tend to fail for newly fallow areas; thus, we assumed that if the model failed to fit a particular pixel, there were likely no crops in that pixel for that year. Crops, especially winter wheat, tend to peak sooner than vegetation growing on fallow fields; in addition, the NDVI during the peak of the growing season tends to be higher for crops than for vegetation growing on fallow fields. Accordingly, we identified the following classification rules and applied them to all pixels with a crop probability higher than 0.75:

1) If models fail → *no crops.*

If the peak height > µ *peak height* – σ *peak height*

AND peak timing (in AGDD) <
< *1100AGDD* → *crops.*

where µ *peak height* is the average of the peak heights per pixel based on the years 2002 through 2009 and σ *peak height* is the standard deviation of the peak heights per pixel for the same years. We evaluated several cut-off degrees for AGDD and determined that a cut-off of 1100 degree days generates the most accurate results. We validated the results against statistical yearbook data indicating the number of hectares with successfully sown crops for each year separately between 2004 and 2008.

RESULTS AND DISCUSSION

1. Spatial differentiation of agriculture in Samara oblast

There are three aspects of spatial differentiation of agriculture: natural setting, location on the center-periphery axis, and ethnic makeup [Nefedova 2003]. We address these aspects in that order.

The natural setting of Samara oblast can be delineated ecoclimatically: the transition between forest-steppe and steppe is approximately at the latitude of the city of Samara (Fig. 3). As one proceeds south, patches of forests disappear and aridity increases. It reflects both natural (i.e., pertaining to biomes) and acquired agricultural contrasts between the north and the south of the region. In the next

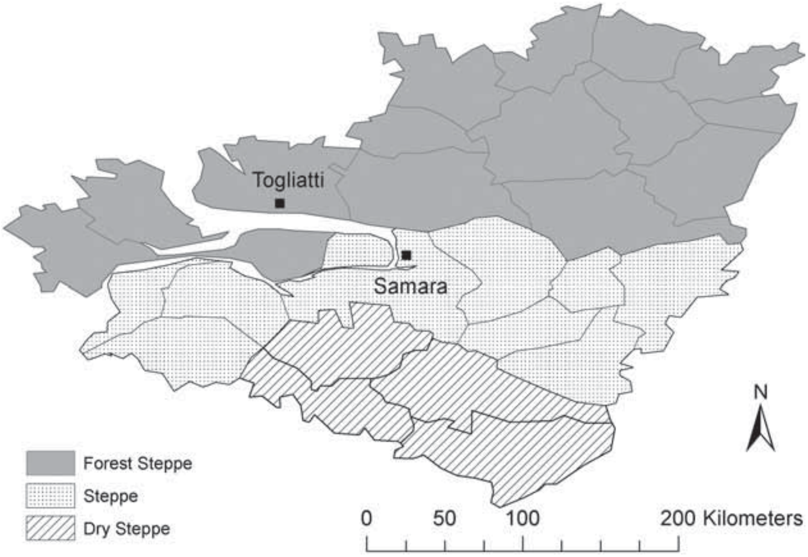

Fig. 3. Natural areas: forest steppe, steppe, dry steppe

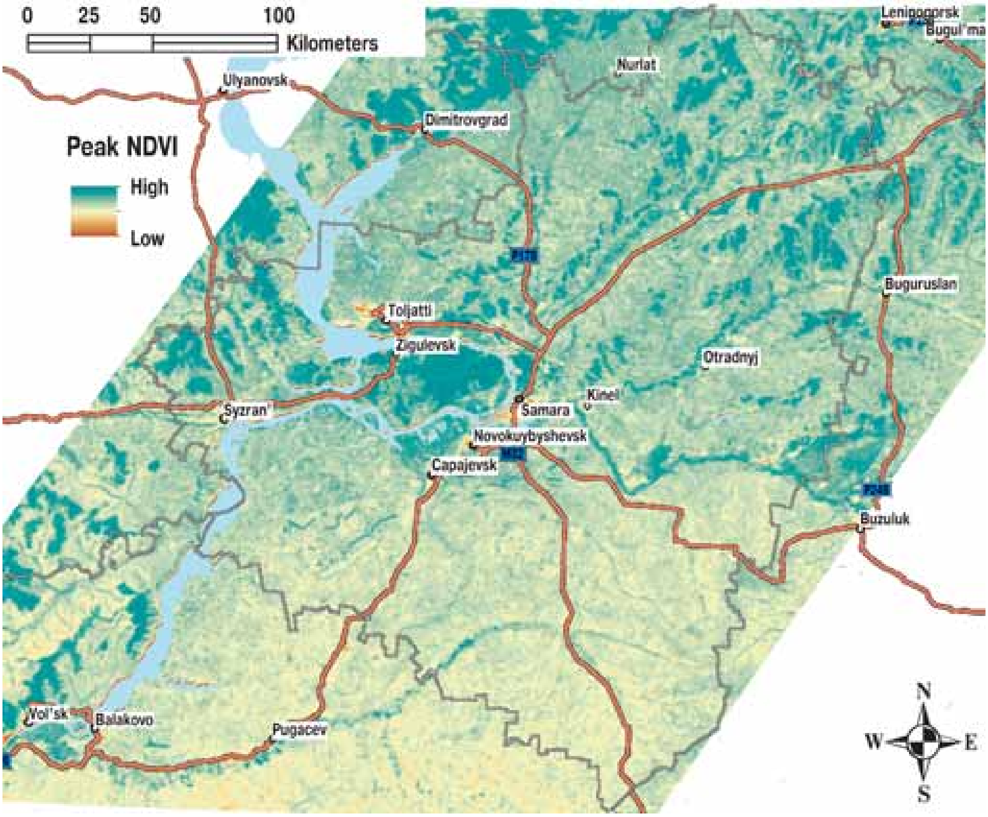

Fig. 4. Peak NDVI in Samara oblast based on satellite observations

step we analyze the phenological metrics defined above within each of the three steppe regions.

The land surface phenology models provide a sufficiently good fit for our further analyses: the average coefficient of determination (R^2) of the quadratic phenology model linking AGDD and NDVI for all pixels and all years (2002-2009) was 0.84. Based on the land surface phenology models we found that the average start of the vegetative growing season for Samara occurred on April 14 (day 104). However, the start of the growing season occurred about a week earlier for forested areas in the study region (day 96) and about a week later for croplands (day 112). Thus, the difference in the start of the growing season between the forested areas and the croplands is a little more than two weeks. We did not find significant differences in the start of the vegetative growing season for the three natural zones. The average start of the vegetative growing season was April 14 (day 104) for the forest steppe region, April 15 (day 105) for the steppe region and April 18 (day 108) for the dry-steppe region. Figure 4 provides the peak height for Samara. The average peak height of the growing season (measured in NDVI) is 0.72 with much higher peak values for forested areas (~0.8) compared to croplands (~0.65). Forested areas typically have denser vegetation cover than croplands resulting in higher peak heights. The peak height for both agricultural and non-agricultural areas is highest in the forest-steppe region (~0.71 and ~0.8, respectively). The peak height is lowest in the dry-steppe region (~0.65 and ~0.69, respectively). The difference between agricultural and non-agricultural areas is smaller in the dry steppe than in the forest steppe as a result of the makeup of the land cover in the regions (forest vs. grasslands).

On average the thermal time to the peak of the growing season was 1516 GDDs. The thermal time to peak is about 100 growing degree days later for agricultural areas than for non-agricultural areas in the dryland steppe. In the other regions, the thermal time to peak is later for non-agricultural areas: 23 growing degree days for the dry steppe and 46 growing degree days for the forest steppe region. The difference in the average time to peak for the agricultural regions and the non-agricultural regions is very small and insignificant. However, the agricultural areas while portraying a similar annual average, reveal much greater temporal variability. The inter-annual coefficient of variation (100 • standard deviation/mean) for the thermal time to peak is more than twice as large for agricultural areas as for non-agricultural areas in the forest steppe and steppe areas. For example, the coefficient of variation, calculated based on the years 2002 through 2009 is 23.8% for the agricultural regions, but only 11.7% for the non-agricultural regions. The dry steppe region reveals the smallest difference in coefficient of variation between agricultural and non-agricultural areas (29.2% for agricultural areas versus 17.0% for non-agricultural areas). The difference between the three different steppe regions is most likely a result of the makeup of the non-agricultural land cover which is predominantly grasslands in the dryland steppe, a mix of grassland and forests in the steppe and predominantly forests in the forest steppe.

The second aspect of the spatial differentiation has to do with the Samara-Togliatti urban agglomeration (Fig. 5). Districts adjacent to Samara and Togliatti (suburbs) have the highest population density and the highest livestock density. Though significant, these center-periphery productivity gradients are less pronounced than in the northern or non-black-earth half of European Russia.

The third aspect of spatial differentiation is ethnicity (Fig. 6). In the region's northeast, ethnic Russians are less than half of the population, and Chuvash, Tatars, and Mordvins communities are widespread.

Performance of large (collective) farms in the different zones, based on grain yields and on milk yield per cow, shows that the suburbs have had the highest yield, followed by the semi-suburbs (rayons that are second-order neighbors of large cities) and the remaining zones. Milk yields declined everywhere prior

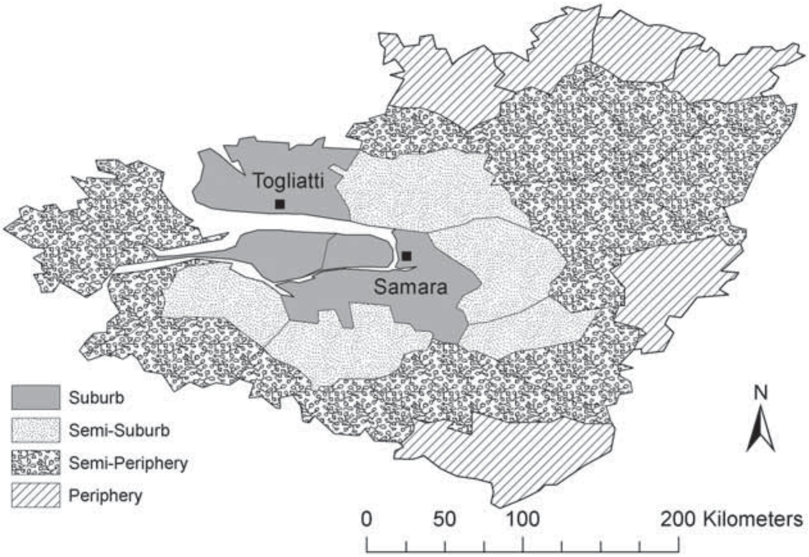

Fig. 5. Center-periphery contrasts: suburb, semi-suburb, semi-periphery, and periphery

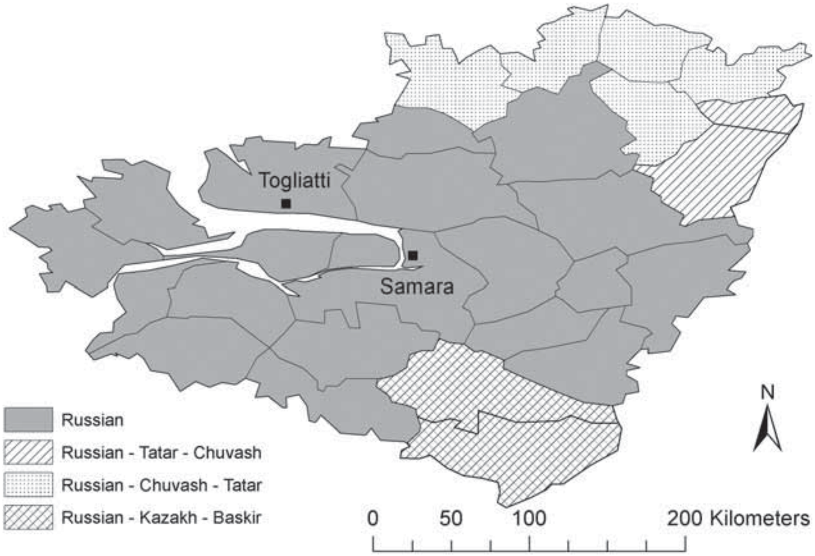

Fig. 6. National areas:

Russian; Russian–Tatar–Chuvash (Russian – less than 35%, Tatars – 20–80%, Chuvash – 5–25%); Russian–Chuvash–Tatar (Russian – less than 40%, Chuvash – 20–40%, Tatars – 5–20%); Russian–Kazakh–Bashkir (Russian – 60–80%, 4–10% of Kazakhs, Bashkirs 4–10%)

to 2000 and grain yields prior to 1997. After growth resumed, suburbs, semi-suburbs, and the districts on the East bank of the Volga River fared the best. Southern peripheral farms where the number of cattle has declined particularly sharply fare the worst.

In the household sector, spatial differentiation is also significant. For example, because large farms in the south have disposed of most cattle, the number of cattle on household farms is now at its highest in the south. In this zone and also in the ethnically mixed zone in the northwest, most large farms are strapped for cash and prefer to pay shareholders in kind (by grain), which stimulates animal husbandry on household farms [Pallot and Nefedova 2007]. In the suburbs, people do not hold a lot of cattle. At the same time, in the semi-peripheral zone, production of vegetables exceeds their consumption by a factor of four to five; here, household farms are de facto commercial producers of vegetables.

In the independent commercial farms (IF) sector, suburbia leads in terms of the sheer number of registered IFs. However, IFs have small land holdings in that zone. For example, in the Stavropol district (north of Togliatti), IF have on average 10 ha, grow potatoes and vegetables, and control about 4% of all farmland. In terms of IF's share of farmland, semi-suburb and southern zones lead, producing mostly grain; whereas, the zone with the highest share of non-Russians trails all the other zones.

2. Change in agriculture

From 1991 to 2000, gross agricultural output in Russia had declined by 40%, including by 60% in the collective-and-state-farm sector. Agricultural change in Samara Oblast approximates that of Russia as a whole, not only in terms of the overall output but also in terms of cattle (a drastic decline) and cropland (shrinkage) dynamics. From 1999 to 2009, growth in Russia's overall agriculture as well as Samara's was steady. While agriculture in Samara has left the crisis behind, its specialization is changing. As in much of Russia, crop farming is gaining ground and animal husbandry is fading into the background. Thus, the share of crops

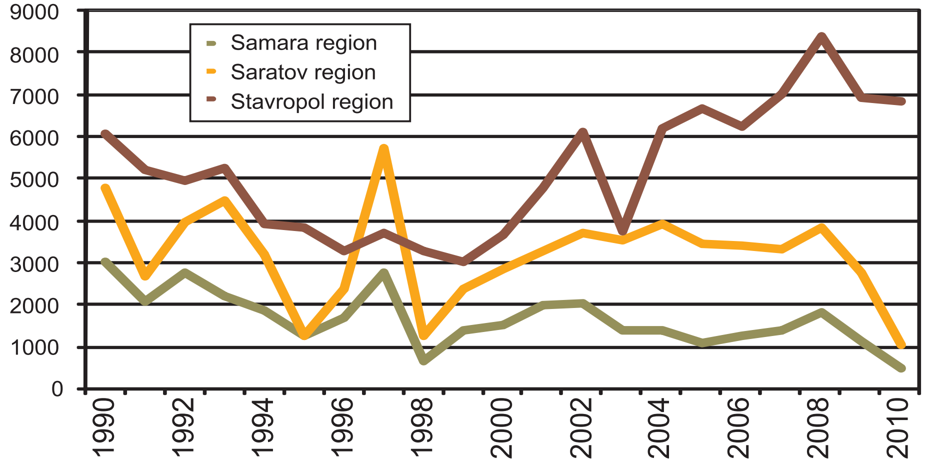

Fig. 7. The annual gross output of grain crops in the Volga region and in the Stavropol Territory in 1990–2010's, thousand tons.

Sources: *[Agriculture in Russia, 1998, 2002; Agriculture, hunting and forestry, 2004; Russia's Regions, 2008, 2010; Socioeconomic, 2011]*

in gross agricultural output increased from 41% in 1991 to 60% in 2003, only to slightly decline in subsequent years (to 56% in 2008). This change was largely conditioned by a drastic decline in cattle – from 1,012,000 head in 1991 to just 212,000 in 2008, although the numbers of pigs and poultry have been growing since 1997. The major specialization of Samara's agriculture is grain. However, due to periodic droughts, its output is unstable (Fig. 7). From 1970 to 2008, the coefficient of variation of grain output was as high as 37%. Grain in Samara is mainly produced on large farms (former collective and state farms). In addition, household farming operations are quite important, and many household farms are de facto commercial, that is, they are actively participating in market economy without registering as independent commercial farms (IF) and consequently without paying taxes on output, particularly in the grain and sunflower sectors.

Having emerged in the early 1990s, registered IF increased in numbers until 1996 and then began to decline. In the meantime, however, a number of the strongest IF took shape and began to expand. Today, the average size of Samara IF 90 ha, is 1.5 times that in Russia as a whole, and in the southern, drought-prone districts some IF reach 1000 ha. About two-thirds of IF land is sown with grain, which along with sunflower generates the bulk of IF profit. One has to keep in mind, though, that IF tend to under-report their output in order to evade taxes, and up to half of IF file no financial reports at all. In addition, IF can hardly employ as many people as collective farms once did, and they are even less likely to enter into symbiotic relationships with household farms (like former collective farms do). Thus, the implications of putative IF expansion across the entire countryside are ambiguous at best.

3. Changes in cropped areas

One of the peculiarities of the entire Volga Federal District, including Samara Oblast, is the large amount of land fallowed as a way to restore natural fertility. Altogether from 30% to 40% of arable land was fallowed up to 2009 (Fig. 8 and 9). Thus, the gap between cropland and total arable land amounts to ~900,000 ha. Part of that fallowed land (7%-8% of the total arable land) is actually abandoned. From 1990 to 2008, cropping area contracted almost everywhere, but particularly (by 40%) in the suburbs and on the east bank of the Volga River. Alongside the crisis of the 1990s, there have been competing claims on that land, including

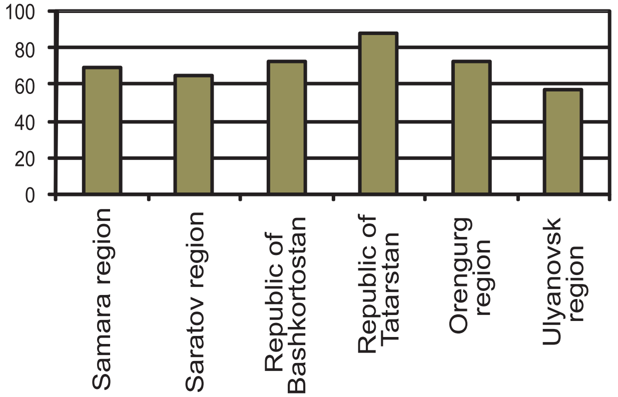

Fig. 8. 2009 area sown with crops as a percentage of that in 1990.

Source: *[Russia's Regions, 2010]*

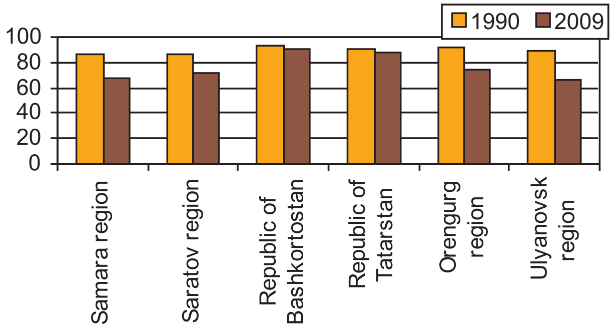

Fig. 9. Percentage share of the area sown with crops in the total arable land

demand generated by the dachniks, i.e., owners of summer homes.

By evaluating the phenological characteristics of the MODIS curves for each year, we determined annually whether a pixel was actually cropped or left fallow. We have compared the satellite estimated cropped areas with regional statistics (by rayon) and found that R^2_{adj} for the years 2004 through 2008 ranged between 0.86 and 0.92 (Fig. 10). We conclude that we can accurately estimate the total area cropped by rayon. Our satellite analysis confirms the relatively large amount of fallow land in Samara found in the agricultural statistics. Between 2002 and 2009 about 26% of the agricultural land was fallow with the highest amount of fallow land in 2009 (33%). The forest steppe region reveals the least amount of fallow land (17.6%), followed by the steppe region (21.4%). The dry steppes have the most fallow land (26.4%). Figure 11 provides a spatial overview of the number of times a particular area was cropped between 2002 and 2009.

Since 2000, shrinkage of cropland has stopped, and in some districts it has been reversed (Fig. 12, 13, 14, and 15). Returning abandoned land to agricultural use is much easier in the steppe biome than in the forest biome. Recovery of abandoned land has been particularly active in the south, in the semi-suburbs, and on the right bank. The share of cereals in the overall area sown with crops has been on the rise in the dry steppe districts of the south; by 2004 that share had reached 72% (Fig. 13). Such a dominance of grain disrupted the traditional crop rotation schedules and led to soil fatigue. By 2008, however, the share of cereal crops had declined to the initial 65%. In the districts where cereal crops did not dominate, as was

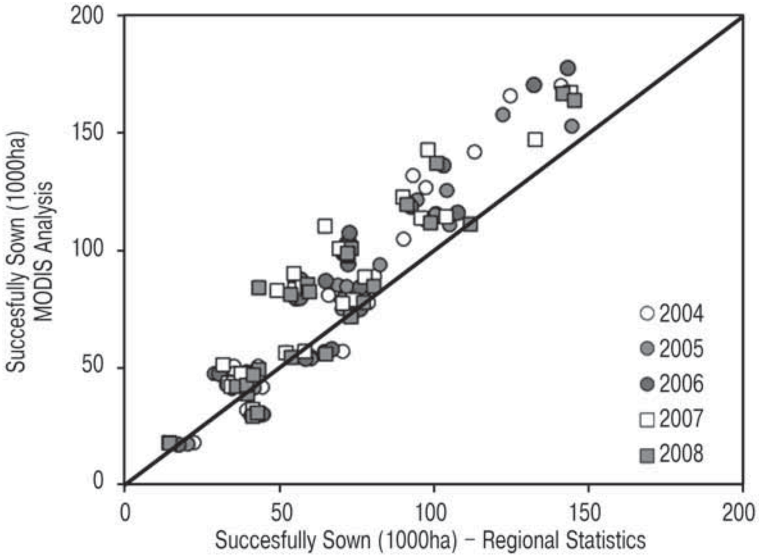

Fig. 10. The total area successfully sown by district of Samara region as observed by satellite data compared to the successfully sown data from regional statistics

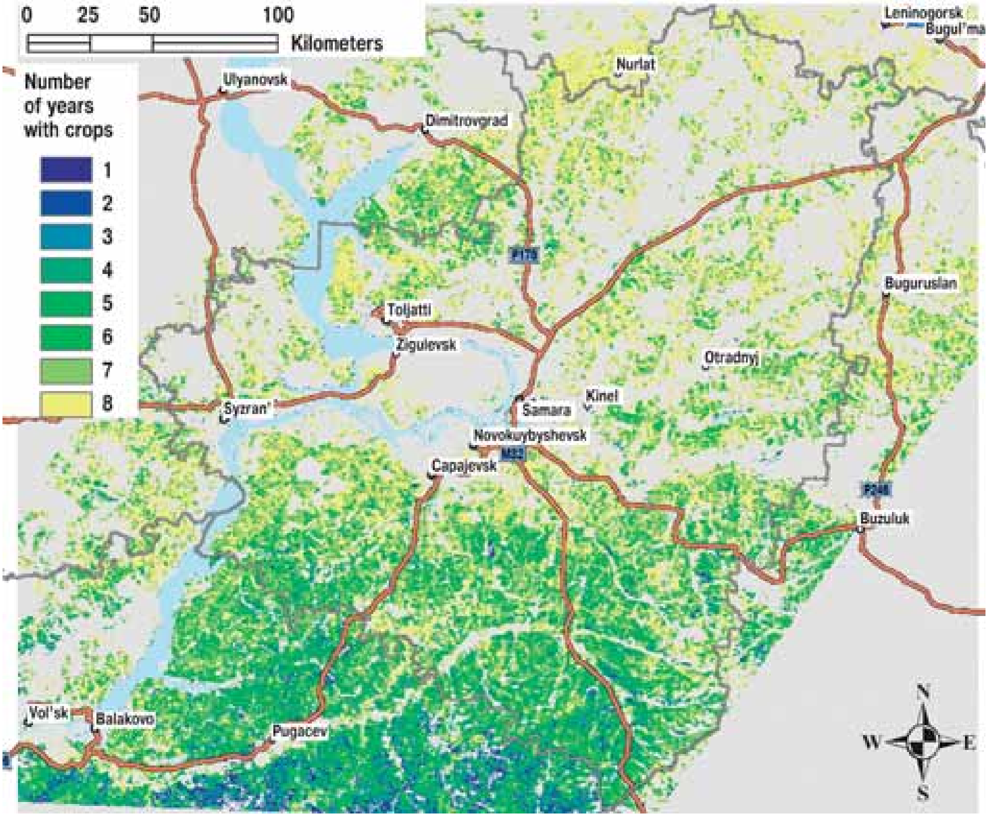

Fig. 11. Number of years with successfully sown crops between 2002 and 2009. Darker blue areas have fewer successfully sown crops (3–4 years). Greener areas have more successfully sown crops (6–8 crop years). Southern areas are troubled by droughts

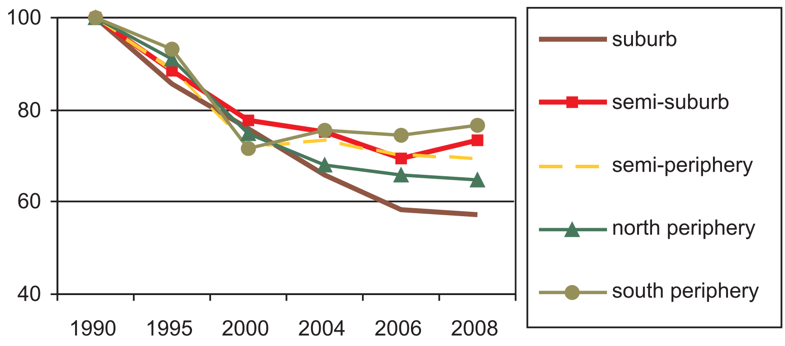

Fig. 12. Area under cultivation in different zones of Samara region as a percentage of that area in 1990.

Source: *[Agriculture, 2009]*

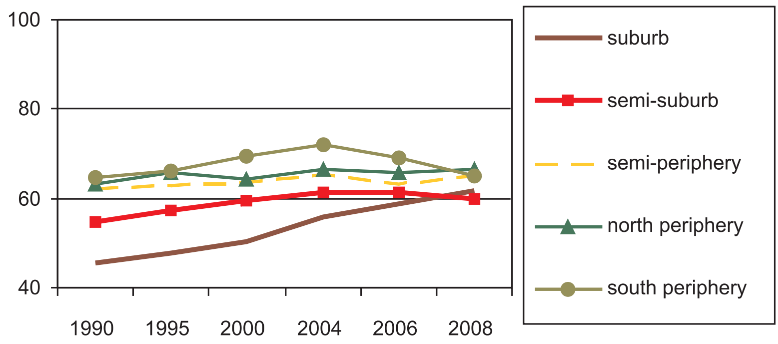

Fig. 13. Area sown with cereal crops in different zones of Samara region as a percentage of that area in 1990.

Source: *[Agriculture, 2009]*

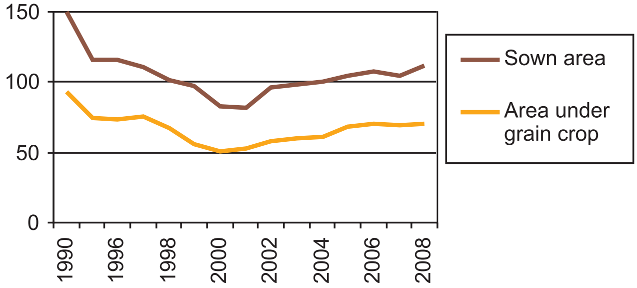

Fig. 14. Sown area and the area under cereal crops in the steppe Kinel-Cherkassy district in hectares

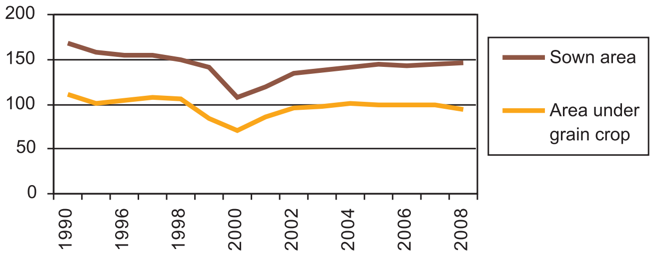

Fig. 15. Sown area and the area under cereal crops in the arid southern district Bolshechernigovsky in hectares

the case in the suburbs and semi-suburbs, the share of these crops has risen considerably. In the remaining districts, the *makeup* of the crops has not changed much, although along with returning formerly abandoned fields into cultivation (the process underway since 2000), the *acreage* under cereal crops expanded (Fig. 14 and 15).

CONCLUSIONS

The major aspects of agricultural change in the studied region of Samara are drastic declines in animal husbandry and shifts in crop rotation with emphases on fallowing more land than before for the sake of restoring fertility. In addition, there is a marked increase in sunflower cultivation, which ensures a higher profit margin as compared with cereal crops. The overall amount of land under cultivation sharply declined in the 1990s but has rebound since then. The spatial differentiation in the size of land sown with crops and the proportions of the three types of farms (former collective farms, household farms, and independent commercial family farms) depend on such drivers as distance from the two major cities, susceptibility to drought, and ethnic makeup. Land surface phenology metrics confirm the natural spatial differentiation of Samara oblast. The interannual coefficient of variation of the thermal time to peak is much larger in agricultural areas than in non-agricultural areas and this difference depends on the location of an area within Samara. Satellite analyses confirm the large amount of fallow land in Samara ranging from 17.6% in the northern forest steppe region to 26.4% in the southern dry steppes.

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