



## Patterns and drivers of post-socialist farmland abandonment in Western Ukraine

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### ARTICLE INFO

#### Article history:

Received 13 August 2010

Received in revised form 4 November 2010

Accepted 8 November 2010

#### Keywords:

Land-use transitions

Fallow fields

Carpathians

Remote sensing

Support Vector Machines

Regression analysis

### ABSTRACT

Farmland abandonment restructures rural landscapes in many regions worldwide in response to gradual industrialization and urbanization. In contrast, the political breakdown in Eastern Europe and the former Soviet Union triggered rapid and widespread farmland abandonment, but the spatial patterns of abandonment and its drivers are not well understood. Our goal was to map post-socialist farmland abandonment in Western Ukraine using Landsat images from 1986 to 2008, and to identify spatial determinants of abandonment using a combination of best-subsets linear regression models and hierarchical partitioning. Our results suggest that farmland abandonment was widespread in the study region, with abandonment rates of up to 56%. In total, 6600 km<sup>2</sup> (30%) of the farmland used during socialism was abandoned after 1991. Topography, soil type, and population variables were the most important predictors to explain substantial spatial variation in abandonment rates. However, many of our *a priori* hypotheses about the direction of variable influence were rejected. Most importantly, abandonment rates were higher in the plains and lower in marginal areas. The growing importance of subsistence farming in the transition period, as well as off-farm income and remittances likely explain these patterns. The breakdown of socialism appears to have resulted in fundamentally different abandonment patterns in the Western Ukraine, where abandonment was a result of the institutional and economic shock, compared to those in Europe's West, where abandonment resulted from long-term socio-economic transformation such as urbanization and industrialization.

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### Introduction

Land-use change strongly affects ecosystems, their services and biodiversity, and ultimately human well-being (Foley et al., 2005). A better understanding of the patterns of land-use change and what drive these spatial patterns is therefore a key challenge for landscape ecology and land-use science (Global Land Project, 2005; Turner et al., 2007). Trajectories of intensifying land use, particularly agricultural expansion in the tropics, are fairly well understood (Geist and Lambin, 2002; Hansen et al., 2008). However, land use can also become less intense as societies industrialize and urbanize, resulting in landscapes characterized by farmland abandonment and reforestation (Lambin and Meyfroidt, 2010; Rudel et al., 2009, 2010). Such shifts of socio-ecological

systems characterized by deforestation to systems with forest increase have occurred in Western Europe (Gellrich et al., 2007; Mather et al., 1999) and North America (Kauppi et al., 2006; Rhemtulla et al., 2009) during the 19th and 20th centuries, and more recently in parts of Central America (Marin-Spiotta et al., 2009), and southeast Asia (Fox et al., 2009). Overall though, farmland abandonment rates and patterns remain unclear in many regions worldwide.

This is worrisome, because land abandonment affects ecosystems profoundly (Rey Benayas et al., 2007; DLG, 2005). For example, abandonment decreases soil erosion (Tasser et al., 2003), increases carbon sequestration (Marin-Spiotta et al., 2009; Vuichard et al., 2008), improves water quality (Kramer et al., 1997), and may allow biodiversity to recover (Chazdon, 2008). Conversely, abandonment decreases agricultural production often permanently, because recultivation is expensive once forests have established (Larsson and Nilsson, 2005). In places with long land-use histories, farmland abandonment also threatens cultural identity and bio-

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diversity associated with traditional land-use practices (Elbakidze and Angelstam, 2006; Palang et al., 2006; Plieninger et al., 2006).

Eastern Europe and the former Soviet Union are a prime example of a region with widespread farmland abandonment. The breakdown of socialism in 1991 and the shift from centralized planned towards market economies resulted in a profound restructuring of Eastern Europe's agricultural sector (Lerman, 1999; Mathijs and Swinnen, 1998). Prices for inputs and agricultural products were liberalized, budget constraints introduced, guaranteed markets within the Eastern Block disappeared, and foreign competition emerged (Ioffe and Nefedova, 2004; Lerman et al., 2004; Turnock, 1998; Lerman and Shagaida, 2007). Massive ownership transfers of land and capital assets occurred, often resulting in tenure insecurity (Mathijs and Swinnen, 1998). Moreover, substantial migrations away from rural areas occurred (Ioffe et al., 2004). Not surprisingly, official statistics suggest this triggered farmland abandonment at unprecedented rates (DLG, 2005; Henebry, 2009; Ioffe and Nefedova, 2004; Kuemmerle et al., 2008).

The problem is that agricultural statistics for the former Soviet Union are often outdated or difficult to compare before and after 1989 and of doubtful quality. Remote sensing is a well known alternative to assess large scale land-use change (Potapov et al., 2008), and especially Landsat satellites are known to be well suited to assess abandonment rates. For example, Landsat Multi-spectral Scanner imagery (MSS) showed that 32% of the farmland used in Estonia during socialism was abandoned between 1990 and 1993 (Peterson and Aunap, 1998). Similarly, Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) images revealed abandonment rates of up to 21% between 1989 and 2000 in the northeastern Carpathians (Kuemmerle et al., 2008), 52% between 1989 and 2000 for the Smolensk region in European Russia (Prishchepov et al., submitted for publication), 12% between 1991 and 2001 in the greater Olomouc region, located in the northeast of the Czech Republic (Vaclavik and Rogan, 2009) and 21% in southern Romania from 1990 to 2005 (Kuemmerle et al., 2009b). Visual interpretation of high-resolution imagery also showed that 50% of all farmland in Latvia was abandoned during the first 10 years of the transition period (Nikodemus et al., 2005), but abandonment rates were only 7% in Albania for the period of 1988–2003 (Müller and Munroe, 2008). Although these studies emphasize the potential of remote sensing to map post-socialist abandonment, almost all existing work has focused on small study regions in only a handful of Eastern European countries. Thus, abandonment rates in many regions remain unquantified.

Existing work also showed that abandonment rates differed substantially, both within and among countries (Ioffe et al., 2004; Kuemmerle et al., 2008; Müller et al., 2009), and that raises the question about the drivers of these patterns. Quantitative evidence from Eastern Europe to answer this question is scarce, but studies elsewhere in Europe suggest that mainly four categories of variables determine spatial patterns of abandonment. First, environmental variables such as topography and soil quality determine the suitability of farming and can therefore be important determinants of abandonment (Gellrich et al., 2007; MacDonald et al., 2000; Rey Benayas et al., 2007). Remote fields and pastures often require disproportional management effort because fields are dispersed. An increasing distance to markets also diminishes land rents (Baldock et al., 1996; Gellrich and Zimmermann, 2007; Müller et al., 2009). Thus, fields located in remote areas likely have a higher tendency to become abandoned once declining subsidies stop compensating non-profitable farming in such areas. Third, population change is an important driver of farmland abandonment, because rural population decline results in a decreasing farmland demand and a diminishing rural workforce (Verburg and Overmars, 2009;

Yeloff and van Geel, 2007). Finally, changes in the input intensity of farming (e.g., fertilizer, and mechanization) can have marked effects on abandonment rates. High-intensity farming typically manages large arable areas and focuses on the most productive sites, thus triggering abandonment in marginal areas (Baldock et al., 1996; Plieninger, 2006).

To our knowledge, only three studies have assessed determinants of farmland abandonment quantitatively. In southern Romania, topography and local market access were the main determinants of farmland abandonment, whereas population parameters did not influence abandonment patterns substantially (Lakes et al., 2009; Müller et al., 2009). Conversely, population density and marginality for farming explained abandonment in Albania (Müller and Munroe, 2008). In addition to these studies, descriptive analyses suggest that topography, population density, migration, ownership regime, and land reform strategies also may have influenced post-socialist farmland abandonment (e.g., Kuemmerle et al., 2008; Sitko and Troll, 2008). A comprehensive assessment of post-socialist farmland abandonment drivers across larger areas in Eastern Europe, however, is missing.

Western Ukraine is a particularly interesting region to study patterns and drivers of post-socialist farmland abandonment, because it comprises a large variability in environmental conditions, including areas of favorable farming conditions (i.e., fertile soils and long growing period) and marginal farming (e.g., mountain regions). Likewise, the region is characterized by varying socio-economic conditions and different cultural traditions in use of natural resources. Field evidence also suggests that farmland abandonment in Western Ukraine was widespread after 1991, when Ukraine became an independent state.

The overarching goal of our study was to (a) map post-socialist farmland abandonment in Western Ukraine and (b) relate abandonment patterns to environmental, accessibility, population, and land use intensity variables. Specifically, we tested four hypotheses: post-socialist farmland abandonment rates are higher:

1. in areas of higher elevation, steeper slopes, and poorer soils;
2. in remote areas afar from market centers;
3. in areas with decreasing (rural) population density;
4. where the intensity of farming decreased most.

## Methods

### Study area

Our study region in Western Ukraine covers about 48,000 km<sup>2</sup> and consists of three oblasts (i.e., Ivano-Frankivska, Lvivska, and Zakarpatska) with 47 rayons. Rayons are district-level administrative units in Ukraine (equivalent to the NUTS-3-level in the European Union, or the county-level in the United States). Elevation in the study region varies from 75 to 2061 m and the region contains almost the entire Ukrainian Carpathians as well as adjacent plains (Fig. 1). Main rivers in the regions are Dniester, Prut, and Tysmenytsia. Soils vary throughout the study region with Cambisols and Podisols dominating in the mountains, and albelvisols, phaeozems, and fluvisols in the lowlands. Climate is temperate continental with slightly warmer conditions in the southwest (e.g., mean temperature of 9.6°C in Uzgorod) compared to the northeast (7.2°C in Lviv), while annual precipitation is around 740 mm (Kruhlov et al., 2008; NESDIS, 2009).

Approximately 5.2 million people live in the study region, one-third in cities (State Statistics Committee of Ukraine, 2001). The plains and Carpathian foothills are relatively densely settled. Agriculture is the main land use in the plains and foothills, and forestry

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