Lost in transition: determinants of post-socialist cropland abandonment in Romania

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The transition from command to market-oriented economies drastically affected land ownership and land management in Eastern Europe and resulted in widespread cropland abandonment. To examine these phenomena, we analysed the causes of post-socialist cropland abandonment in Argeș County in southern Romania between 1990 and 2005. Based on Landsat-derived maps of cropland use and a suite of environmental and socioeconomic variables hypothesized to drive cropland abandonment, we estimated spatially explicit logistic regression models for two periods (1990–1995 and 1995–2005) and three elevation groups. Our results showed that isolated cropland patches were more likely to become abandoned than more homogenous cropland areas. Unfavorable topography was an important determinant of abandonment in the plain and, to a lesser extent, hilly areas, but not in the mountains where locations with adverse market access and higher farm fragmentation exhibited higher likelihoods of cropland abandonment.

Keywords: cropland abandonment; logistic regression; spatial model; land-use change; Romania; Eastern Europe

1. Introduction

Land-use practices are the main reason for the conversion of natural ecosystems into human-dominated landscapes (Foley \textit{et al.} 2005; Kareiva, Watts, McDonald, and Boucher 2007), particularly in the tropics where croplands continue to replace forests at high rates (Lepers \textit{et al.} 2005; Hansen \textit{et al.} 2008). However, in other areas of the world, land-cover trajectories have reversed when countries reach an industrialized stage, as well as when population size stabilizes (Mather and Needle 1998; Rudel \textit{et al.} 2005). This often results in a twofold pattern of intensified cultivation in areas favourable for farming, and the abandonment of cultivation where farming conditions are marginal (Baldock, Beaufoy, Brouwer, and Godeschalk 1996; MacDonald \textit{et al.} 2000; Strijker 2005).

Cropland abandonment has widespread effects on ecosystem services, for example, increased carbon sequestration when cropland reverts back to forests (Silver, Ostertag, and Lugo 2000), decreased soil erosion (Tasser, Mader, and Tappeiner 2003), or increased water quality (Hunsaker and Levine 1995). On the other hand, traditional cultural landscapes are increasingly lost where cropland is abandoned (Government Service for Land and Water Management 2005; Palang \textit{et al.} 2006), which often results in the decline of biodiversity.
Cropland abandonment is often triggered by broad-scale political or socioeconomic shocks (Yeloff and Van Geel 2007). Central and Eastern European countries have experienced drastic and rapid changes in their political and socioeconomic structures since the collapse of socialist regimes. The departure from command economies was accompanied by a restructuring of the respective farming sectors, as well as land reforms that triggered massive ownership transfers of both natural resources and capital assets (Mathijs and Swinnen 1998; Lerman, Csaki, and Feder 2004; Rozelle and Swinnen 2004). Rural population compositions have changed dramatically due to large internal and external migration movements, especially of younger population segments (Angelstam, Boresjo-Bronge, Mikusinski, Sporrong, and Wastfelt 2003; Palang et al. 2006; Müller and Munroe 2008)."
from 1990 to 2005 (Kuemmerle, Müller, Griffiths, and Rusu 2009). Building upon this work, the focus here is on assessing the underlying causes of cropland abandonment, the largest post-socialist land use in Argeș County. To accomplish this, we linked cropland abandonment from two time periods (1990–1995 and 1995–2005) to a suite of bio- and geophysical, socio-economic, and policy-related variables using spatially explicit logistic regressions models. Beforehand, we hypothesized that variables affecting agricultural suitability and farm profits, as well as rural population dynamics, were the prevailing factors that contributed to cropland abandonment in Argeș County. Specifically, our objectives were as follows:

1. To quantify the direction and strength of the causal influences of each variable on cropland abandonment during the two periods.
2. To compare the causal influence of the variables in the regression model for the entire study area with models estimated for three elevation subgroups.

2. The study area

We studied Argeș County in central Romania (Figure 1) because the region encompasses a wide range of environmental conditions. The county is part of the historical province

![Figure 1. Study area. Source: Authors.](image-url)
Muntenia and covers an area of 6826 km$^2$, has a mean annual rainfall of 750 mm and a mean annual temperature of 7°C. Predominant soil types are Argillic soils in the plains, Cambisols in the hilly areas, and Podzols in the mountainous areas. Biogeophysical variables show clear north–south patterns. For instance, elevation and rainfall are higher in the north, whereas temperature is lower.

The southern region of Argeș County consists of a plain (<250 m above sea level), whereas the hilly zone (250–1500 m) contains the county’s capital and major market center Pitești (174,000 inhabitants in 2003 (NIS 2004), which is linked to the country’s capital Bucharest by highway. Close to Pitești is the main factory of the carmaker Dacia, the largest private employer in the region. The mountainous northern part of the study area (above 1500 m), a part of the Carpathian Mountains, is characterized by rugged terrain and includes Romania’s highest mountain, the Moldoveanu Peak (2544 m).

3. Data and variables

3.1. Land-cover maps and dependent variables

Land-cover maps for the years 1990, 1995, and 2005 were available from a previous study (Kuemmerle et al. 2009). These maps were generated by classifying the land-cover types forest, cropland, and permanent grassland (including shrubland) from Landsat TM and ETM + images at a spatial resolution of 30 m × 30 m using a hybrid classification approach (Bauer et al. 1994; Kuemmerle, Radeloff, Perzanowski, and Hostert 2006). Settlements, roads, and water bodies were masked prior to classification based on available topographic maps. The accuracy of these land-cover maps was assessed based on a random sample of 765 ground truth points mapped in the field. Overall accuracy was 91.0% (Kappa = 0.86), 92.5% (0.89), and 91.0% (0.86) for 1990, 1995, and 2005, respectively. Land-cover changes were mapped via post-classification map comparison (Coppin, Jonckheere, Nackaerts, Muys, and Lambin 2004), which yielded two change maps for the periods of 1990–1995 and 1995–2005. A detailed description of the change analyses is provided in Kuemmerle et al. (2009).

Cropland decreased strongly in Argeș County during transition, but within distinct spatial clusters (Figure 2). In total, 21% of the cropland was abandoned in 1990, which equaled an area of 512 km$^2$ and represented a decrease from 35 to 28% relative to the county’s area. Cropland abandonment was more prevalent in the 1990–1995 period (17%, equaling 415 km$^2$) compared to the 1995–2005 period (5%, 97 km$^2$) (Kuemmerle et al. 2009).

Patterns of abandonment varied considerably along altitudinal gradients (Kuemmerle et al. 2009). In 2005, cropland covered 70% of the land surface in the plains (1754 km$^2$ of 6286 km$^2$), 11% in the hilly areas, and a mere 2% in the mountains (Figure 3). In the mountainous areas, cropland decreased from 88 to 40 km$^2$ despite a slight increase between 1995 and 2005. In the hilly area, 227 km$^2$ (41% of the 1990 cropland) were abandoned in the first and 68 km$^2$ (21%) in the second period, respectively. In the plains, 170 km$^2$ or 10% were abandoned and almost three-quarters of this decline took place between 1990 and 1995. In sum, Argeș experienced the highest amounts of cropland abandonment in the hilly zone and the highest rates in the mountainous north.
Figure 2. Spatial patterns of cropland abandonment.
Note: Elevation subgroups derived from terciles based on mean commune elevation.
Source: Authors, data from Kuemmerle et al. (2009).

Figure 3. Cropland changes by elevation subgroup.
Source: Authors.
3.2. Cropland density

Land-use change at a particular location often depends on its surroundings. For example, the decision to abandon a cropland pixel may depend on the presence of nearby cropland. The inclusion of a spatially lagged average of the dependent variable as an additional regressor can account for this, but may lead to endogeneity in the lag variable, as well as potentially biased coefficients (Anselin 2002). To control for such endogeneity, we constructed a variable containing the number of neighbouring cropland pixels at the beginning of each change period within a three-by-three window. This approach is similar to Geoghegan, Wainer, and Bockstael (1997) and Geoghegan et al. (2001), who included patterns of surrounding land uses in their estimations to capture the diversity of land use. Gellrich, Baur, Koch, and Zimmermann (2007) used a binary variable if surrounding observations were equal to their dependent variable. Our approach has the additional advantage that it partly controls for potential endogeneity between the dependent and the independent variables by including a temporal lag. Besides, the density variable is an ordinal measure that captures the homogeneity of cropland in the immediate surroundings.

3.3. Time-invariant location factors

We used the Shuttle Radar Topography Mission digital elevation model (DEM) with a spatial resolution of 90 m (Slater et al. 2006). The DEM was used in the classification process (Kuemmerle et al. 2009) and therefore not employed as a covariate. Instead, we calculated terrain roughness (the slope curvature), which is not correlated with elevation. Roughness values were multiplied by a factor of 10 to match the data range of the other variables.

The road network consisted of four different road categories: the highway linking Bucharest with Pitești (category 1), European roads (2), national roads (3), and county roads (4). To assess the influence of road presence on cropland abandonment, three Euclidean distance measures were calculated cumulatively. First, using road categories 1 and 2; second, using road categories 1, 2, and 3; and, third, using all four road categories.

We also include a variable that captured the distance of each location to the northern limit of the study region (subsequently labeled ‘Y coordinate’) to control for spatial dependence in the model residuals (Tasser, Walde, Tappeiner, Teutsch, and Noggler 2007) and to account for the existing north–south gradient. No systematic patterns were observed in the east–west direction and we therefore did not include an X coordinate. We excluded temperature and soil data due to collinearity with the Y indicator variable.

3.4. Rural commune census

A census of all rural communes was carried out in Argeș during the summer and autumn of 2005. Covering socioeconomic and demographic developments, input use, farm fragmentation, and productivity parameters, the census captured exogenous influences, as well as endogenous changes within communes, that were hypothesized to be relevant for cropland abandonment. Municipalities and towns were excluded from the primary data collection because we focused on land use in rural areas. We used a structured questionnaire for group interviews with selected key informants such as commune mayors, agricultural and forestry agents, and cadastral officers. All 16 interviewers were trained in survey and interviewing techniques and carried out the interviews in groups of two. The interviewers were instructed to facilitate a discussion among the respondents to verify and check responses with all
participants. Temporal coverage was achieved through recall techniques (Groves 1989) of landmark events that the respondents could easily remember and that approximately matched the date of the land-cover maps. The first year (1989) depicts the situation during socialism and 1996 was chosen as an intermediate point in time when the Romanian presidential election was held.

We calculated livestock units from the census data to assess the effect of livestock breeding on cropland use. We used the livestock unit coefficients for countries of the Organisation for Economic Co-operation and Development, OECD (Chilonda and Otte 2006). The cattle, sheep, and goat numbers were multiplied by 0.9, 0.1, and 0.1, respectively, and divided by the commune area to yield livestock unit densities as covariates for 1989 and 1996. We further used the number of tractors per commune to proxy agricultural input levels. Several other potentially interesting measures of input intensity (e.g., irrigated area, use of certified seeds, or the use of fertilizer) could not be included due to missing values or lack of variation across the communes. Land reform effects were captured by two variables: First, we used the average number of plots owned by respondents of a commune after land reform implementation. More plots are equivalent to a higher physical fragmentation of the farm, because plot locations are typically noncontiguous. Second, the share of cropland owned by individuals within each commune was calculated to obtain a measure for the type of agricultural production organization. Both variables were only included in the second period because they did not vary significantly in 1989.

3.5. Population and migration proxies

We used interpolation techniques to approximate a spatially continuous population distribution based on the village population data gathered in the rural commune census. This population surface served as a proxy for the demand for cropland at the pixel level. Villages with missing records for 1989 or 1996 (about 10% of the cases) were replaced with official census data from the National Institute of Statistics (NIS 2004). We disaggregated the commune-level population data from the NIS census data to village level by distributing the official data proportionally among the missing villages within a commune. We then calculated the centroids of the village boundaries, linked the population data to these points, and used a third-order inverse distance weighted interpolation to derive continuous population surfaces. Based on visual assessments of the density maps and field experience, we decided to include up to five nearest neighbours and a maximum interpolation distance of 5 km (representing the maximum sphere of spatial influence of inhabitants from a village). This yielded two population density maps, one each from 1989 and 1996. In addition, we included the household density per square kilometer in 1989 and 1996 as independent variables in the models.

Emigration was proxied by the number of individuals who left the commune permanently. The migration variable was the only variable that spanned the entire estimation period, because it was collected for the periods 1989–1996 and 1996–2004. To avoid endogeneity bias (see Section 5.2), we tested the robustness of the emigration variable by estimating the models with and without migration. Coefficients, signs of other variables, and model fit did not change, and we therefore decided to include this potentially important driver in our models. Lastly, temporary emigration in 1996 was included as a variable to capture the economic effect of remittance returns from seasonal migration on cropland abandonment. At the beginning of the 1990s, migration returns were close to zero in all communes and therefore temporary migration was not considered as a covariate in the first estimation period from 1990 to 1995.
3.6. Hypothesized influence of the covariates

In total, we considered 14 covariates that we *a priori* expected to influence cropland abandonment (Table 1). We assumed that undulating terrain (higher roughness) would increase cropland abandonment, as agricultural production may concentrate on locations that are better suited for market-oriented production (MacDonald *et al.* 2000; Ioffe *et al.* 2004). Similarly, we hypothesized higher abandonment at more marginal locations for the variables that proxy road access.

Higher rural population density was assumed to have a negative bearing on land abandonment via the increased demand for cultivated land (Angelstam *et al.* 2003; Ioffe *et al.* 2004). We further expected a lower efficiency of resource consumption per capita in smaller households, as a result of the varying resource use intensity among households and individuals (Liu, Daily, Ehrlich, and Luck 2003). In Argeș County, household size decreased, whereas the number of households increased (own data). Thus, higher per capita consumption in smaller households may have stimulated abandonment, whereas higher household density may have increased cropland demand. Temporary and permanent emigration were unevenly distributed across age groups, with the young and economically active typically being the first to leave. Therefore, emigration possibly induced labour shortages, thereby increasing abandonment (Nikodemus *et al.* 2005; Müller and Munroe 2008).

More tractors per commune (a proxy for agricultural input intensity) potentially increased agricultural production, reflected a higher market orientation and was labour-saving, possibly reducing overall abandonment. On the other hand, labour scarcity due to selective migration could have induced farmers to abandon marginal plots and concentrate their capital and labour inputs on the best plots. Moreover, marginal plots may not be suitable for mechanization. Thus, the ultimate effect of tractor numbers on the amount of cropland used was *a priori* unclear. The effect of livestock density on cropland abandonment may also have been twofold: Intensive livestock rearing may stimulate fodder crop cultivation, thereby keeping abandonment rates low. On the other hand, extensive livestock production may amplify cropland abandonment due to converting cropland to pastures. Overall, the effect of livestock density on abandonment was unclear *a priori*, because we have no spatial data on the intensity of livestock production.

Table 1. Independent variables with hypothesized influence on cropland abandonment.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Level</th>
<th>Unit</th>
<th>Influence</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Y$ coordinate</td>
<td>Pixel</td>
<td>Kilometers from northern edge</td>
<td>+</td>
</tr>
<tr>
<td>Roughness</td>
<td>Pixel</td>
<td>Mean in 9 x 9 window</td>
<td>+</td>
</tr>
<tr>
<td>Distance to European road</td>
<td>Pixel</td>
<td>100 m from category 1 and 2</td>
<td>+</td>
</tr>
<tr>
<td>Distance to main road</td>
<td>Pixel</td>
<td>100 m from category 1, 2, and 3</td>
<td>+</td>
</tr>
<tr>
<td>Distance to county road</td>
<td>Pixel</td>
<td>100 m from category 1, 2, 3, and 4</td>
<td>+</td>
</tr>
<tr>
<td>Cropland in neighborhood</td>
<td>Pixel</td>
<td>Surrounding number in 3 x 3 window</td>
<td>-</td>
</tr>
<tr>
<td>Population</td>
<td>Pixel</td>
<td>Interpolated</td>
<td></td>
</tr>
<tr>
<td>Household density</td>
<td>Commune</td>
<td>Households per km$^2$</td>
<td>?</td>
</tr>
<tr>
<td>Emigration (permanent)</td>
<td>Commune</td>
<td>Individuals</td>
<td>+</td>
</tr>
<tr>
<td>Temporary emigration</td>
<td>Commune</td>
<td>Individuals</td>
<td>+</td>
</tr>
<tr>
<td>Tractors</td>
<td>Commune</td>
<td>Number</td>
<td>?</td>
</tr>
<tr>
<td>Livestock density</td>
<td>Commune</td>
<td>Units according to OECD per km$^2$</td>
<td>?</td>
</tr>
<tr>
<td>Cropland owned individually</td>
<td>Commune</td>
<td>% of cropland</td>
<td>-</td>
</tr>
<tr>
<td>Parcels</td>
<td>Commune</td>
<td>Average number per farm</td>
<td>+</td>
</tr>
</tbody>
</table>

Source: Authors.
More plots owned by a household (the farm fragmentation proxy) presumably resulted in production inefficiencies via increased labour requirements and reduced the effectiveness of and the incentive for mechanization (van Dijk 2003), thereby fostering abandonment. Similarly, land owned by the state or by legal and family associations may have been more likely to be kept in cultivation due to higher input use and mechanization levels, as well as better access to financial capital.

4. Statistical approach

4.1. Data integration and sample selection

We combine the variables derived from the commune census with the spatially explicit data based on the commune boundaries by assigning the same value for all pixels within a commune. All calculations were conducted using a spatial resolution of 28.5 m to match the land-cover maps, resulting in 8,395,490 observations within Argeş County. All grids were converted to integer values to reduce computing time and the distance measures were rescaled to 100 m steps to facilitate the interpretation of the statistical results.

The final data set was the result of five sampling steps. First, an inside buffer of 1 km was erased from the boundary of the study area to avoid influences from neighbouring counties (Müller and Zeller 2002). This buffer size was based on visual inspection, but sensitivity tests with larger buffer sizes did not alter the results. Second, spatial coding was carried out to select non-adjacent pixels at a specified distance from the nearest selected neighbour to reduce spatial autocorrelation in the response variable (Besag 1974; Nelson and Hellerstein 1997). To choose an appropriate distance between selected observations, we tested different coding schemes ranging from distances of 6–15 pixels between selected neighbours, and decided to use a distance of 9 pixels (228 m) as a compromise between the correction of spatial dependency among observations and the rapidly decreasing number of observations.

Third, only observations that were covered by cropland at the beginning of the respective change period were selected. In that way we accounted for the temporal dependence of cropland abandonment on the state of land cover at the start of the respective period (Tasser et al. 2007; Müller and Munroe 2008). This also ensured that abandoned pixels in the first period did not affect coefficients in the second period. Fourth, disproportionate (or balanced) sampling was applied to the binary-dependent variable, because the number of observations with stable cropland (= 0) was much larger than the number of abandoned pixels (= 1) – as is often the case in land-use/land-cover studies (Serneels and Lambin 2001; Gelrich et al. 2007). We randomly selected 1000 observations from both the presence and absence group. Such disproportionate sampling in logistic regression analysis does not affect the coefficients, but can affect the constant term and, therefore, the predicted probabilities (Maddala 2001). The constant has to be decreased by \( \ln(p_1) - \ln(p_0) \) to obtain correct predictions, where \( p_1 \) and \( p_0 \) are the proportions of the sampled observations from the presence and absence group, respectively, and \( \ln \) is the natural logarithm.

The models were estimated for the entire study area (hereafter called the global model). Although such results can be highly relevant for policy-making, global models average out the spatial heterogeneity (Osborne and Suarez-Seoane 2002). This may be especially problematic for an ecologically diverse region such as Argeş County. We, therefore, calculated elevation terciles for the mean elevation within a commune to obtain three elevation subgroups that displayed high elevation homogeneity within a group, but strongly differed from each other. Three additional models (local models) were fitted for the elevation subgroups that are subsequently referred to as the plain model, hilly model, and mountain
model for the low, the medium, and the high elevation terciles, respectively. Every subgroup contained 31 communes, but they differed in their spatial extent (and the number of pixels) due to varying commune sizes. We employed identical sampling strategies for the subgroups and randomly selected 500 abandoned and 500 non-abandoned observations.

4.2. Estimation strategy

To understand the causal determinants of cropland abandonment in Argeș County at the pixel and at the commune level, we fitted maximum likelihood-based binary logistic regressions. Two logistic regression models of cropland abandonment were estimated, one for the 1990–1995 period and one for the 1995–2005 period. Estimating two change periods allowed us to describe the temporal changes in the influences of the independent variables that affected the use of cropland. All time-variant variables were included using values from the beginning of the respective change period. We consider these temporally lagged variables as exogenous covariates of cropland abandonment, because the lags avoid the endogeneity bias which arises from a possible simultaneity of cropland abandonment and the covariates (Müller and Zeller 2002; Perz and Skole 2003). This assumes that later abandonment did not influence the state of a variable at the beginning of the respective period. This regression setup allows us to go beyond mere associations between variables and permits, in connection with field-based evidence, causal interpretations of the effects of the independent variables on cropland abandonment.

The multilevel data structure required corrections to ensure the independence of observations. Pixels within communes may exhibit dependence, whereas pixels across communes are more likely to be independent (Müller and Munroe 2005; Overmars and Verburg 2006; Gellrich et al. 2007). To control for these within-group effects, robust estimation techniques were employed that account for potential correlations within communes. We used a variant of the Huber and White estimator that affects the variance-covariance matrix by estimating robust standard errors, but leaves the estimated coefficients unaffected (Froot 1989; Gutierrez and Drukker 2005). Within-group adjustment also has the additional advantage of controlling for potential spatial autocorrelation in the residuals by accounting for correlations of observations within communes (Gellrich et al. 2007).

In total, eight models were estimated: one global and three local models for each of the two periods. The variance inflation factor (VIF) was used in all models to test for multicollinearity in the covariates. VIF assesses whether the variance of one explanatory variable is independent from all other explanatory variables (Chatterjee, Hadi, and Price 2000). The only variable that had to be deleted from the subgroup estimations (but not the global model) was the \( Y \) coordinate, which was positively and significantly correlated with terrain roughness. No serious multicollinearity was detected for all other variables with a mean VIF below 1.5 and the largest VIF below 10. Several ad hoc methods to correct for spatial effects were employed: the \( Y \) coordinate (Section 4.3) in the global regressions, the coding scheme (Section 5.1), and the roughness variable, which was included as a spatial average in a nine-by-nine rectangular window (Nelson, Harris, and Stone 2001).

The degree to which the statistical estimations explain the occurrence of land abandonment was assessed using five goodness-of-fit statistics: First, McFadden’s adjusted \( R^2 \) (adj. \( R^2 \)) was used to assess the regression fit. Adj. \( R^2 \) is a common measure in logistic regressions that accounts for the number of parameters included (Ben-Akiva and Lerman 1985). Second, the percentage of correctly predicted observations (PC) was calculated from the predicted probabilities by assuming the highest predicted probability as the predicted value. Third, the area under the curve (AUC) of the receiver operating characteristics (ROC) was estimated
using a nonparametric ROC curve (Metz 1978). The AUC measures the share of the correctly predicted positive (abandoned) from all predicted positive values against the share of the correctly predicted negative (stable cropland) against all negative values. The AUC is derived by varying the probability threshold, which results in an AUC between 0.5 for a random map and 1.0 for a perfect prediction (Pontius and Schneider 2001). Fourth, the Kappa statistic quantifies the locational accuracy between predicted and observed data compared to a random map (Cohen 1960). A perfect prediction yields Kappa = 1 and Kappa approaches 0 if correct predictions are equal to those of a random map. Last, we calculated the Bayesian Information Criterion (BIC), which compares subgroup models by judging the distance between the fitted model and the observed data based on the log-likelihood function (Schwarz 1978). The more negative the BIC, the better the model fit.

5. Results
The regression results suggested that the determinants of cropland abandonment varied considerably for the elevation subgroups in significance and strengths of the influences. Globally, the density of cropland and topography were important determinants while market access and farm fragmentation emerged as driving factors of cropland abandonment in the hilly and mountainous areas.

5.1. Descriptive statistics of covariates
The concentration of cropland in neighboring locations at the beginning of the respective period showed the strongest relationship with cropland abandonment (Figures 4 and 5), suggesting that abandonment was more likely to occur where cropland was less homogenous. The extent of abandonment was higher further north (lower \( Y \) coordinate) and at locations with rougher terrain in the first and second period. In the second period, abandonment was associated with proximity to roads, which was indicated by lower medians and lower ranges of the road distance variables. Fewer tractors per commune in both periods and a larger share of individually owned cropland in the second period appeared to be connected with the occurrence of cropland abandonment. No clear relationship was found for the other independent variables.

5.2. Determinants of cropland abandonment
Goodness-of-fit statistics for the eight logistic regression models are summarized in Table 2. The two global models displayed excellent fit with AUC of 0.84 (81% correct predictions) and 0.89 (79%) for the periods of 1990–1995 and 1995–2005, respectively. Kappa was good with 0.48 and 0.43. The model fit was somewhat lower for the three elevation subgroups, especially for the first period in the plain and mountainous areas. The models performed reasonably well for hilly areas in both periods and considerably better for the plains in the second period. Models for the mountainous areas showed lower goodness-of-fit in both periods with AUC of 0.7.

To facilitate the readability of the results (in total, more than 100 coefficients plus associated statistics), we omitted the tables with coefficients, standard errors, and \( p \)-values. Instead, we chose a graphical description of the estimation results. Figure 6 visualizes the odds ratios, their 95% confidence intervals, and \( p \)-values in a compact form, with one graph for each independent variable. Each plot in Figure 6 contains the global and subgroup
Figure 4. Box plots of independent variables by cropland abandonment, 1990–1995.
Note: Yes = abandoned; no = stable cropland. The box plots omit outliers, that is, observations below (above) 1.5 times the interquartile range of the first (third) quartile. See Table 1 for the units of the variables. For the sake of brevity, the box plots are not shown for the elevation subgroups, but can be obtained from the authors upon request.
Source: Authors.
Figure 5. Box plots of independent variables by cropland abandonment, 1995–2005.
Source: Authors.
regressions for both periods to facilitate comparability of models. Coefficients with significance levels below 20% were omitted.

The concentration of cropland in neighbouring locations had the largest quantitative impact on the occurrence of abandonment. In the global model, one additional pixel of cropland in the immediate neighbourhood decreased the odds of abandonment by 19% (equivalent to an odds ratio of 0.81) in the first period and by 28% in the second period. Spatially homogenous cropland patterns were particularly important in the plains, where an additional cropland pixel in the neighbourhood decreased the likelihood of abandonment by 34% in both periods. In the hilly area, the decrease was about 17% in both periods, whereas in mountains the decrease in the odds ratio was considerably lower.

Terrain roughness had a significant influence on cropland abandonment in most models with the expected positive sign. While the effect was small in the mountainous subgroup during the first period and vanished in the second, terrain undulation was associated with increased abandonment in areas of low and medium elevation. The global model masked this elevation-specific effect.

The effects of distance to the European and main roads were insignificant or small in both periods. But pixels located farther away from county roads were more likely to become abandoned in the hilly and mountainous subgroup in both periods. This effect was largest in the mountains and between 1995 and 2005, when the probability of abandonment increased by 7% every 100 m further away from a local road. Road access did not substantially affect abandonment in the plains. At the county level, local variations of road influence averaged out.

Our models did not reveal strong quantitative evidence for a relationship of cropland abandonment with population and household density or migration. Higher population density counteracted cropland abandonment for the entire study area in the second period, but was insignificant for the elevation subgroups. Household density made abandonment less probable in the first period and more probable in the second. Permanent and temporary emigration had a small negative influence in the mountainous subgroup during the second period.

Globally, a higher density of livestock decreased the likelihood of abandonment in the second period. Again, the global results masked subgroup variations. For example, in the hilly areas a higher livestock density was associated with higher abandonment in both

<table>
<thead>
<tr>
<th>Period</th>
<th>Elevation subgroup</th>
<th>Adj. $R^2$</th>
<th>PC</th>
<th>AUC</th>
<th>Kappa</th>
<th>BIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990–1995</td>
<td>Plain</td>
<td>0.047</td>
<td>0.519</td>
<td>0.667</td>
<td>0.038</td>
<td>−5,533</td>
</tr>
<tr>
<td>1990–1995</td>
<td>Hilly</td>
<td>0.124</td>
<td>0.677</td>
<td>0.746</td>
<td>0.354</td>
<td>−5,639</td>
</tr>
<tr>
<td>1990–1995</td>
<td>Mountainous</td>
<td>0.079</td>
<td>0.529</td>
<td>0.711</td>
<td>0.058</td>
<td>−5,576</td>
</tr>
<tr>
<td>1995–2005</td>
<td>Plain</td>
<td>0.250</td>
<td>0.620</td>
<td>0.828</td>
<td>0.240</td>
<td>−5,800</td>
</tr>
<tr>
<td>1995–2005</td>
<td>Hilly</td>
<td>0.092</td>
<td>0.657</td>
<td>0.720</td>
<td>0.314</td>
<td>−5,580</td>
</tr>
<tr>
<td>1995–2005</td>
<td>Mountainous</td>
<td>0.064</td>
<td>0.596</td>
<td>0.696</td>
<td>0.185</td>
<td>−5,430</td>
</tr>
<tr>
<td>1990–1995</td>
<td>Global</td>
<td>0.294</td>
<td>0.741</td>
<td>0.844</td>
<td>0.481</td>
<td>−13,177</td>
</tr>
<tr>
<td>1995–2005</td>
<td>Global</td>
<td>0.369</td>
<td>0.714</td>
<td>0.892</td>
<td>0.427</td>
<td>−13,368</td>
</tr>
</tbody>
</table>

Note: The global (subgroup) estimations are based on 2000 (1000) observations with 1000 (500) observations from the present and absent group, respectively (Section 5.1).

Source: Authors.
Figure 6. Odds ratios, $p$-values, and confidence intervals for the logistic regressions.
Source: Authors.
periods. Finally, higher farm fragmentation within a commune positively influenced the likelihood of cropland abandonment in the mountainous region, where the regression results suggest that the ownership of an additional parcel per farmer increased the odds of abandonment by 28%. Farm fragmentation had no measurable effect on cropland abandonment in the hilly and plain areas.

6. Discussion

The study region underwent drastic changes in livelihood strategies, which shaped land use and land cover during the post-socialist period. Cropland abandonment was widespread in Argeş County and most of this abandonment occurred at the onset of transition. Cropland became more stable between 1995 and 2005, but abandonment proceeded at high rates in some areas. Cropland abandonment differed notably by topographic conditions. The highest absolute decrease was observed in hilly areas, whereas the highest abandonment rate was found in the mountains. We identified topographic variables, the spatial homogeneity of cropland use, and accessibility as the most important determinants of this process. However, the influence of these drivers differed considerably among elevation subgroups in significance and strength of influence.

The logistic regression models for the entire county fitted the data very well. The explanatory power of the models for the elevation subgroups was lower, particularly in the mountainous areas in both periods and in the plains in the first period. Reasons for the lower fit were possibly the small variation of commune-level data in the subgroup models. In addition, only half as many observations entered the regressions in the subgroup models. Nevertheless, the subgroup results emphasized that great care is required when interpreting and inferring from the results of one regression model for a study region as large and diverse as Argeş. Global coefficients masked important subregional variations and only disaggregating the study area along a topographic gradient revealed remarkable local variations in the determinants of cropland abandonment.

For example, more isolated patches of cropland were more likely to become abandoned, but this effect was three times stronger in the plains compared to the hilly or mountainous subgroups in both periods. This result may in part reflect the patchiness of the agricultural landscape in the mountainous areas, where many of the small and isolated plots remained in cultivation, albeit at low cultivation intensities. Cropland in the plains had a larger tendency to become more homogenous over time. The higher commercial orientation of farmers and the higher share of legal and family associations in the plains may have contributed to this trend toward more consolidated land-use pattern in the plains.

Cultivation in the plain and hilly areas was significantly more likely on flat terrain, indicating the importance of topographic variation in agricultural production. In the mountains, terrain roughness had no discernible effects; rather, adverse road access and higher farm fragmentation contributed to cropland abandonment. Higher transportation costs may have reduced the profitability of farming to the point where farmers gave up cultivation on remote plots. Higher farm fragmentation negatively affected the change in cropland area in the mountainous areas. We assume that the higher fragmentation may have become a critical factor for cropland use for the low-intensity, semi-subsistence farming systems in the mountains, because it increased labour and management requirements. Higher input requirements may have induced farmers to stop cultivating on marginal plots.

Population and migration proxies were weaker predictors of cropland abandonment than expected. Several reasons may explain their small or insignificant influence. First, the insecure status of many emigrants may have prompted people to keep land in cultivation
in order to reduce the risks involved in migration. In addition, land rentals are sometimes pursued on a yearly basis for a small return in cash or kind (own data). The effect of emigration on abandonment in the southern plains may have been further absorbed by legal associations or state farms that rent in land on a year-by-year basis from labour-scarce families. Second, a great deal of domestic migration was temporary and many emigrants return for peak work periods to help those who have stayed behind. And occasionally, the migrants’ remittances may serve to hire in additional labour. Third, our data do not capture the age structure of farming households. Many are in retirement age and may soon discontinue farming, while the younger generations attempt to find work elsewhere and are unlikely to return (Cartwright 2003).

From a macroeconomic perspective, we suggest two major trends contributed to the high amount of cropland abandonment in Argeş. First, the ratio of output to input prices was deteriorating in agriculture during the post-socialist transition (Rozelle and Swinnen 2004). This development is apparent in Romania for example, in the decreasing share of agriculture in the gross domestic product from 24% in 1990 to 10% in 2005 (World Bank 2007). Concurrently, the opportunity costs of agricultural labour were rising across Eastern Europe, which encouraged part of the workforce to move away from agricultural employment toward other economic sectors, similar to processes observed in Western Europe in the past (Strijker 2005). But, contrary to other East European countries, agricultural employment in Romania did not decrease substantially after 1989 and there was less emigration from rural areas (World Bank 2007). Yet official statistics may not capture several important demographic processes that affect cropland use such as the loss of younger population segments, rural–urban commuting, and seasonal migration (Dorondel 2007; Kuemmerle et al. 2009). Commuters and temporary emigrants often continue to be registered in rural areas, thus resulting in biased agricultural workforce estimates.

A limited number of income opportunities began to emerge in rural tourism in the northern part of the study area along the foothills of the Carpathians, where the amount of tourist accommodation has increased significantly (NIS 2004; Dorondel 2007). Low-input farming may continue in such areas, as it is an essential element of the landscape that attracts visitors and generates income. Such monetary incentives may have been one factor in the slowdown of abandonment between 1995 and 2005 in the mountainous subgroup. The plain areas in the south possess more suitable natural conditions and better market access, both of which have benefited the development of profitable farming. Farming structures include larger management units, which possibly reduced abandonment. Farming may be under the highest threat in the hilly areas where the economically active are relocating to the capital Pitești. Farming in the hilly areas is further constrained by difficult terrain conditions and farm structures dominated by small-scale holdings. Abandonment is likely to continue at high rates in the hilly areas without outside interventions.

We conjecture that Romania may have entered a period of accelerated forest transition. Whereas socialism may have slowed down forest expansion because of government support for agricultural production and the largely political decision to provide rural employment, Romania may now start following the economic development pathway of the forest transition (Rudel et al. 2005). Indeed, some of the abandoned cropland has already experienced secondary forest succession (Kuemmerle et al. 2009).

Our analysis can be extended in several ways. First, the inclusion of spatially explicit measures of cultivation intensities may yield valuable additional insights into more subtle land-use modifications, as well as the share of farmers’ market participation. Second, household-level data may better capture socioeconomic and demographic trends in Argeş. For example, household data would provide information on changes in the age structure of
rural households, thereby facilitating the further exploration of emigration’s influence on the labour force. Third, grazing activities were only indirectly incorporated because areas used for fodder production were included in the cropland category. But separating pastures, grassland, and abandoned areas is difficult due to spectral collinearity among these classes. Spatial information on livestock distribution, though challenging to gather, may add to a better understanding of changes in pasture usage during transition.

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Note
1. The tables with the estimation results can be obtained from the authors upon request.

References


