

LAND USE DYNAMICS IN THE SOUTH-CENTRAL
PLANNING REGION (2000–2018): A STATISTICAL
ANALYSIS OF CORINE LAND COVER

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Received on February 28, 2025

Presented by H. Najdenski, Member of BAS, on April 29, 2025

Abstract

This study investigates land use dynamics in the South-Central Planning Region (SCPR) of Bulgaria between 2000 and 2018, a period marked by economic transition and land restitution following the shift from a centrally planned economy. Utilizing CORINE Land Cover data from the European Environment Agency, the research quantifies land use changes across various categories at six-year intervals. The analysis reveals significant transformations, particularly within forest ecosystems where declining mature forests (broad-leaved and coniferous) coincide with increasing transitional woodland-shrub areas, suggesting deforestation and subsequent regeneration. Agricultural systems exhibit complex dynamics, with pasture decline contrasted by vineyard expansion and fluctuating arable land. Urban and infrastructure development shows steady expansion of industrial/commercial units and mineral extraction sites. These findings highlight the complex interplay of human activities and natural processes reshaping the SCPR landscape, providing valuable insights for sustainable landscape planning and management in the region, addressing a critical knowledge gap in understanding post-1989 land use transformation in Bulgaria.

Key words: land use change, CORINE Land Cover, agricultural transformation, South-Central Planning Region

Introduction. In 1989, Bulgaria initiated its transition from a centrally planned to a market-based economy. This transition precipitated significant upheaval in all sectors of the economy, including agriculture [1, 2]. With the commencement of agricultural land restitution [3], parcels, previously consolidated into the so-called Labour Cooperative Agricultural Unions, began to be returned to their original owners and heirs. This process led to the fragmentation of agricultural land, which subsequently altered land use patterns [4–7]. Consequently, monitoring land use changes is crucial as it provides valuable insights into the evolving relationship between human activities and the environment. By tracking these changes, researchers can assess their impacts on ecosystems, such as habitat loss and fragmentation, which directly affect biodiversity. Furthermore, it enables the understanding of how land-use transformations influence socio-economic systems, including agricultural productivity, urban development, and resource availability, ultimately informing sustainable land management practices and policies.

The South Central Planning Region (SCPR) is one of Bulgaria’s six NUTS 2 planning regions [8]. It encompasses 2.23465 million hectares and is administratively divided into five districts: Plovdiv, Pazardzhik, Smolyan, Kardzhali, and Haskovo. The total population was 1 302 828 [9]. SCPR is situated in the central-southern part of the country and is characterized by a diverse landscape and a combination of socio-economic activities. The region exhibits varied topography (Fig. 1), including the Rhodope Mountains, the Upper Thracian Plain, and

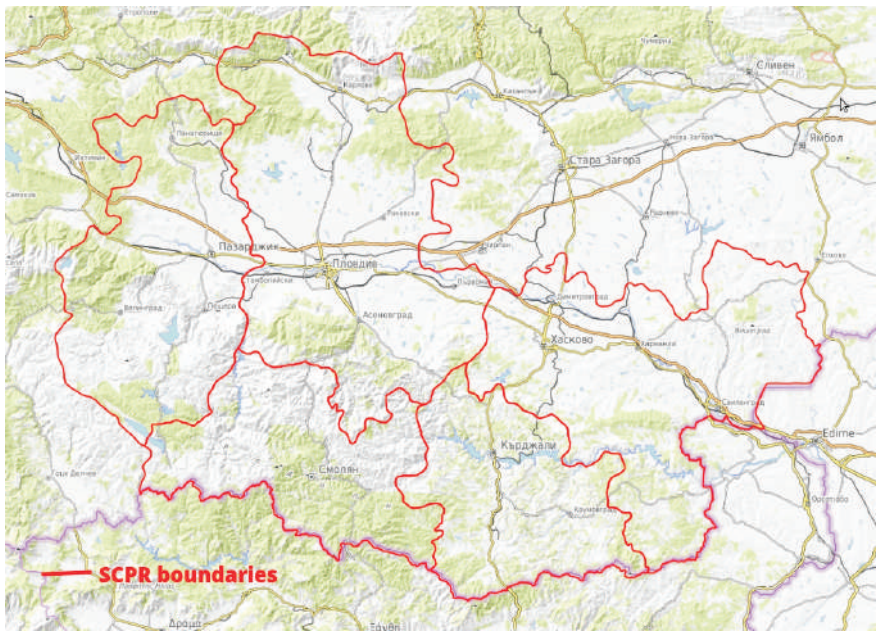


Fig. 1. Topographic map of SCPR. Source: OpenTopoMap

parts of Sredna Gora, while being traversed by major rivers such as the Maritsa and Arda. Socioeconomically, the SCPR is distinguished by both urban centres and rural communities facing challenges related to employment, infrastructure development, and regional disparities, while also possessing a rich cultural identity and historical significance [10]. Environmentally, the region encompasses diverse ecosystems, including protected areas and important habitats, necessitating a balance between economic development and conservation efforts [11].

Therefore, understanding land-use dynamics within the SCPR, particularly in the context of post-1989 land restitution and economic restructuring, is essential for informed planning and sustainable development in the region. Despite the documented impacts of land restitution and economic transition on Bulgarian agriculture since 1989 [1, 2, 4, 6], a comprehensive, spatially explicit assessment of land use change dynamics in the South Central Planning Region (SCPR) remains a critical gap in knowledge. While some localized studies may exist, there is a notable absence of region-wide analysis utilizing satellite data to quantify and characterize the complex patterns of land use transformation in the SCPR.

This study aims to address this critical knowledge gap by providing the first comprehensive assessment of land use change in the SCPR using satellite data. By employing remote sensing techniques and spatial analysis, we quantified and characterized the patterns of land-use transformation over a defined period, offering valuable insights for stakeholders involved in regional planning, environmental management, and sustainable development.

Materials and methods. Four datasets of land use were utilized: Corine Land Cover 2000, 2006, 2012, and 2018 (raster 100 m) from the European Environment Agency [12]. Raster layers were employed for the assessment due to certain known issues with the vector layers of Corine land cover [13].

OpenTopoMap [14] was employed to visualize the topography of the SCPR terrain.

The QGIS software [15] was utilized to process and visualize the obtained data. WSG84 / UTM zone 35N coordinate reference system was implemented. Raster layers were vectorized using the Poligonize function, and polygon areas were calculated using the area function.

Linear regressions, land use changes and their visualizations were conducted using Python software [16] in the Jupyter Notebook environment [17].

Results and discussion. The CORINE (Coordination of Information on the Environment) [18] Land Cover methodology represents a standardized European approach to environmental mapping and monitoring. This methodology utilizes satellite-based remote sensing to generate land cover inventories at a scale of 1:100 000 with a minimum mapping unit of 25 ha and a minimum width of 100 m for linear elements. The classification system encompasses 44 land cover classes organized into three hierarchical levels. Class 1 comprises artificial surfaces, agricultural areas, forests and semi-natural areas, wetlands, and water bodies. The

T a b l e 1

Land use classes areas (in hectares) in the South-Central Planning Region for the years 2000, 2006, 2012, and 2018 based on CORINE Land Cover data

Year Class number and name [18]	2000	2006	2012	2018
1.1.1 Continuous urban fabric	34	34	34	34
1.1.2 Discontinuous urban fabric	61192	61225	61285	61285
1.2.1 Industrial or commercial units	11072	11214	11713	11840
1.2.2 Road and rail networks and associated land	251	251	397	435
1.2.4 Airports	1080	1080	1080	1080
1.3.1 Mineral extraction sites	3312	3362	3533	3705
1.3.2 Dump sites	721	721	855	840
1.3.3 Construction sites	144	298	106	168
1.4.1 Green urban areas	494	494	489	489
1.4.2 Sport and leisure facilities	1870	1870	1875	1889
2.1.1 Non-irrigated arable land	461638	462097	460766	462233
2.1.2 Permanently irrigated land	80	80	80	80
2.1.3 Rice fields	33286	33355	33349	33898
2.2.1 Vineyards	32600	32401	34068	33729
2.2.2 Fruit trees and berry plantations	11293	10873	10856	10381
2.3.1 Pastures	53139	53065	52423	51590
2.4.2 Complex cultivation patterns	67160	67154	67161	67228
2.4.3 Land principally occupied by agriculture with significant areas of natural vegetation	245477	245453	245348	245438
3.1.1 Broad-leaved forest	411037	408421	407966	407364
3.1.2 Coniferous forest	272367	270642	268998	266021
3.1.3 Mixed forest	227049	226037	225683	225772
3.2.1 Natural grasslands	104060	104029	103786	103062
3.2.2 Moors and heathland	1161	1161	1161	1161
3.2.3 Sclerophyllous vegetation	10	10	10	10
3.2.4 Transitional woodland-shrub	204530	210133	212050	215340
3.3.1 Beaches, dunes, sands	798	798	798	798
3.3.2 Bare rocks	303	303	303	303
3.3.3 Sparsely vegetated areas	4771	4771	4771	4771
3.3.4 Burnt areas	417	14	44	44
4.1.1 Inland marshes	369	369	369	369
5.1.1 Water courses	6141	6141	6141	6141
5.1.2 Water bodies	18731	18731	19089	19089

mapping process employs computer-assisted photointerpretation of satellite imagery, supplemented by ancillary data and ground verification. Updates are produced at six-year intervals.

The data presented in Table 1 illustrates the temporal evolution of diverse land use classes over an 18-year period, spanning from 2000 to 2018, with measurements obtained at 6-year intervals (2000, 2006, 2012, 2018). This comprehensive longitudinal dataset facilitates the analysis of changes in land cover and land use across various categories as defined by the CORINE Land Cover classification system.

Artificial surfaces. Continuous urban fabric (1.1.1) remained stable at 34 hectares throughout the entire period, indicating no expansion of dense urban cores. Discontinuous urban fabric (1.1.2) exhibited modest growth, increasing from 61 192 to 61 285 hectares (+0.15%), suggesting gradual suburbanization. Industrial or commercial units (1.2.1) experienced more substantial expansion. The graph (Fig. 2, top left) demonstrates a clear positive trend in industrial and commercial land use over the study period. The area increased steadily from 11 072 hectares in 2000 to 11 840 hectares by 2018. The high R^2 value (0.93) indicates that this upward trend accounts for the majority of the variation in the data. This consistent growth reflected sustained economic development and commercial expansion in the region. Construction sites (1.3.3) and dump sites (1.3.2) exhibited high variability, indicating dynamic changes in development areas. The mineral extraction sites (1.3.3) graph (Fig. 2, top right) illustrates a

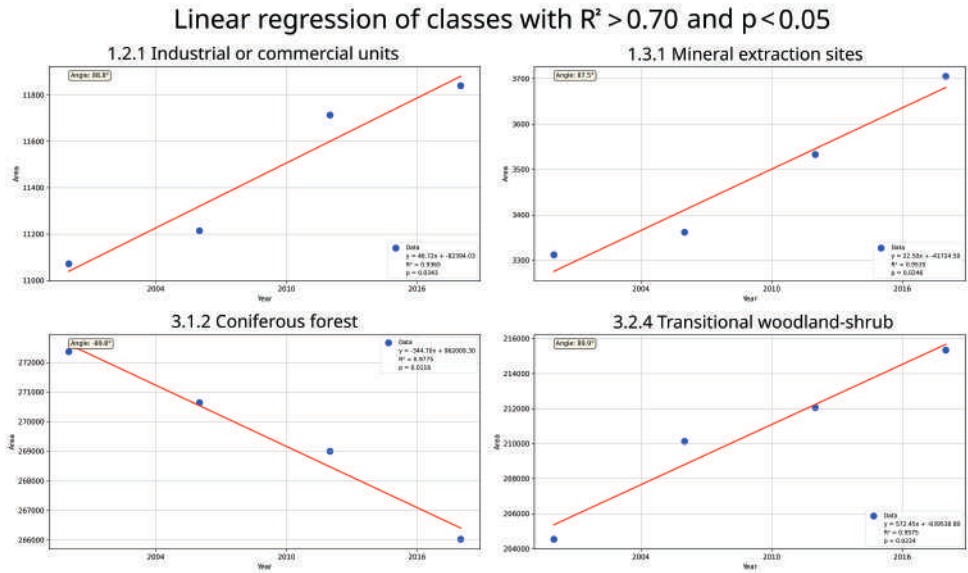


Fig. 2. The most significant linear regression graphs

strong positive linear trend with an R^2 of 0.97. The area dedicated to mining and quarrying increased significantly, growing from approximately 3300 hectares to 3700 hectares. This suggests intensification of resource extraction activities throughout the study period, which may have significant environmental implications. Road and rail networks (1.2.2) increased by 73.3% (from 251 to 435 hectares), demonstrating substantial transportation infrastructure development.

Agricultural areas. Non-irrigated arable land (2.1.1), the largest land use category, showed minor fluctuations with a slight net increase of 0.13%. Rice fields (2.1.3) increased by 1.8% (from 33 286 to 33 898 hectares). Vineyards (2.2.1) experienced growth over the period (+3.5%), indicating expansion of viticulture, suggesting shifts in agricultural priorities. Pastures (2.3.1) decreased by 2.9% (from 53 139 to 51 590 hectares), reflecting a reduction in grazing lands. Complex cultivation patterns maintained remarkable stability over the study period.

Forest and semi-natural areas. Broad-leaved forests (3.1.1) experienced a decline (−0.9%), decreasing from 411 037 to 407 364 hectares. Coniferous forests (3.1.2) showed a more pronounced decrease (−2.3%), from 272 367 to 266 021 hectares. The graph of Coniferous Forests (Fig. 2, bottom left) demonstrates a clear negative trend in coniferous forest cover, with a strong linear relationship ($R^2 = 0.97$). The area has declined steadily from approximately 272 000 hectares in 2000 to about 266 000 hectares by 2018. This consistent loss of coniferous forest represents one of the most statistically significant negative trends in the dataset, potentially indicating systematic deforestation, forest conversion, or impacts from climate change and pest outbreaks. Transitional woodland-shrub (3.2.4) increased significantly (+5.3%), growing from 204 530 to 215 340 hectares (Fig. 2, bottom right) and shows a strong positive trend ($R^2 = 0.94$). This growth in transitional vegetation is particularly interesting when considered alongside the decline in coniferous forests. The inverse relationship between these two classes suggests a possible ecological succession dynamics where mature forests are being disturbed or harvested and subsequently entering early regeneration phases.

Urbanization and infrastructure development was evident as multiple urban and infrastructure-related classes showed increases, although at different rates. Forest dynamics revealed a decline in mature forest classes (broad-leaved, coniferous, mixed) accompanied by an increase in transitional woodland, suggesting possible deforestation followed by regeneration processes or land abandonment. Agricultural shifts were visible in the changes of agricultural land use classes, indicating a transformation in farming practices, with some intensive categories growing while others diminish. A remarkable change occurred in burnt areas (3.3.4) with a dramatic reduction from 417 to 44 hectares, indicating potentially improved fire management or a reduction in fire events.

Some land use classes remained entirely stable throughout the period (e.g., airports, permanently irrigated land, moors, and heathland), while others exhibited either consistent directional trends or fluctuations. This pattern suggests that

land use changes are selective rather than universal, with particular pressures and drivers affecting specific land categories. These stable elements provide important reference points in the changing landscape mosaic.

The heat map (Fig. 3) presents a transition matrix showing the magnitude and direction of changes across the top 15 land use classes with the most significant changes over three time periods: 2000–2006, 2006–2012, and 2012–2018. The colour intensity indicates the magnitude of change, with deep red representing large positive increases and deep blue representing substantial decreases in area.

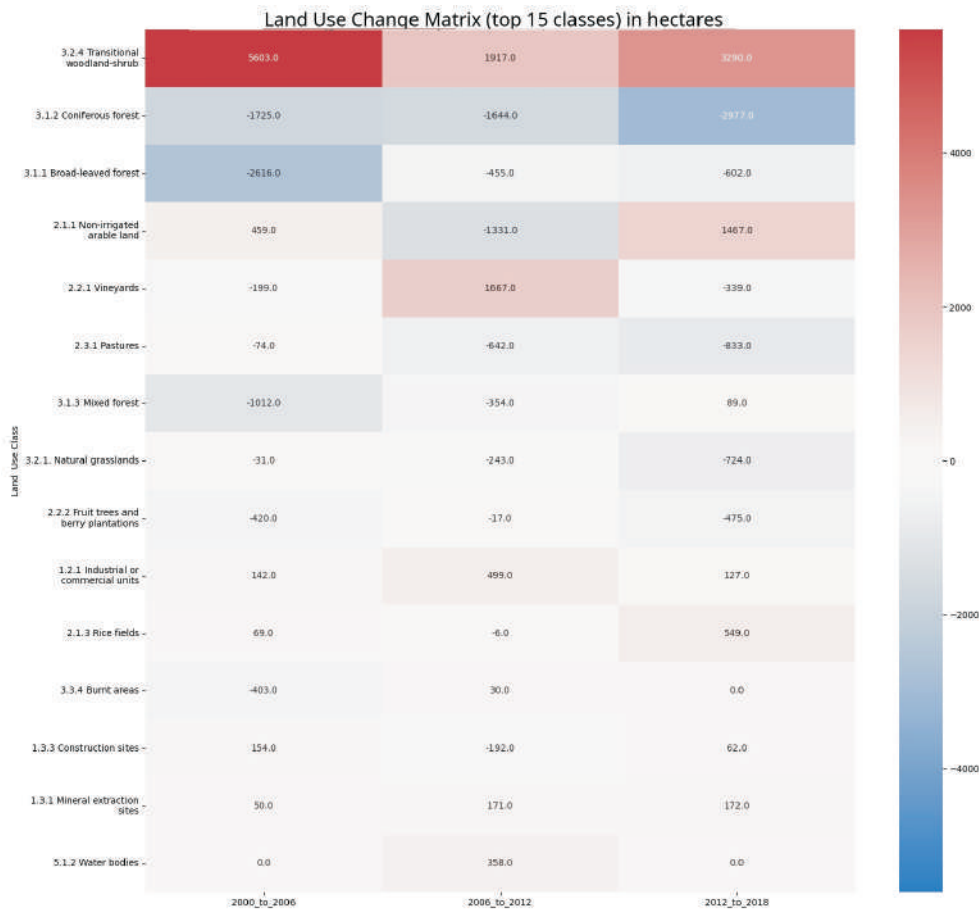


Fig. 3. Largest land use changes in the top 15 classes

Forest dynamics. The most dramatic changes appeared in the forestry categories. Transitional woodland-shrub (3.2.4) showed consistent and substantial increase across all three periods, with particularly large gains in 2000–2006 (+5603 ha) and 2006–2012 (+1917 ha). This contrasted sharply with coniferous forest (3.1.2), which showed consistent losses across all periods, with the most severe decline (−2977 ha) occurring in 2012–2018. Broad-leaved forest (3.1.1) also

experienced consistent losses, particularly in the 2000–2006 period (–2616 ha). Mixed forest (3.1.3) showed the largest decline in the first period (–1012 ha) with smaller losses in the second period.

Agricultural transitions. The agricultural landscape exhibited intricate changes over time. Notably, vineyards (2.2.1) displayed a fascinating trend: they initially decreased by 199 hectares from 2000 to 2006, then underwent significant growth, adding 1667 hectares between 2006 and 2012, and continued to expand by additional 339 hectares from 2012 to 2018. Non-irrigated arable land (2.1.1) fluctuated, increasing initially (+459 ha), then declining significantly (–1331 ha) before rebounding strongly (+1467 ha) in the final period. Pastures (2.3.1) showed a consistent decline pattern, with the largest loss (–833 ha) in the final period. Fruit trees and berry plantations (2.2.2) experienced consistent losses across all periods.

Urban and infrastructure development. Throughout all time periods, industrial/commercial units (1.2.1) exhibited consistent expansion, with the most substantial increase of 499 hectares occurring between 2006 and 2012. Construction sites (1.3.3) showed variability, with increases in the first two periods followed by a smaller gain in the final period. Mineral extraction sites (1.3.1) showed increasing expansion in the later periods, reflecting growing resource extraction activities.

Temporal patterns. The most significant changes in land use occurred between 2000 and 2006, particularly in forested areas, indicating a period of intense transformation. From 2006 to 2012, notable shifts were observed in agricultural landscapes, with vineyards and arable land experiencing substantial alterations. The subsequent period from 2012 to 2018 witnessed ongoing deforestation, but also saw some agricultural sectors showing signs of recovery.

Several limitations of the study warrant consideration. Limited temporal scope: the study only covers the period from 2000 to 2018, with data points at 6-year intervals. This relatively short timeframe may not capture long-term trends or cyclical patterns that occur over decades. Spatial resolution constraints: the CORINE Land Cover methodology [18] used in the study has limitations in terms of spatial resolution. It operates at a scale of 1:100 000 with a minimum mapping unit of 25 ha and a minimum width of 100 m for linear elements. This could result in missing smaller-scale land use changes.

Conclusion. The analysis of land use changes from 2000 to 2018 reveals a landscape undergoing significant, systematic transformations. The most pronounced changes occurred in forest ecosystems, where a clear inverse relationship emerged between declining mature forests (particularly coniferous and broad-leaved) and increasing transitional woodland-shrub areas. This pattern suggests an ongoing cycle of forest disturbance and regeneration, potentially driven by timber harvesting, climate change impacts, or ecological succession processes. The consistency of this trend across all three time periods (2000–2006, 2006–2012,

2012–2018) indicates a sustained rather than episodic transformation of the forest landscape.

Agricultural systems demonstrated complex dynamics and adaptive changes. While some categories like pastures showed consistent decline, others like vineyards exhibited remarkable growth, especially during 2006–2012. Non-irrigated arable land displayed notable fluctuations between periods, suggesting cyclical agricultural practices or responses to changing economic and environmental conditions. Simultaneously, urbanization and infrastructure development proceeded steadily, with industrial/commercial units and mineral extraction sites showing consistent expansion throughout the study period, reflecting ongoing economic development pressures.

The temporal patterns suggested distinct phases of land transformation, with the 2000–2006 period experiencing the most dramatic changes, particularly in forest categories. The heat map analysis revealed that land use changes were selective rather than universal, with certain classes remaining remarkably stable while others underwent significant transitions. These findings highlighted the complex interplay between human activities and natural processes in shaping the landscape mosaic. The strong statistical significance of the observed trends (with high R^2 values for key classes) indicated systematic rather than random changes, pointing to persistent drivers reshaping the regional landscape over the 18-year study period. This understanding of land use dynamics provides valuable insights for sustainable landscape planning and management in the region.

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