One century of pasture dynamics in a hilly area of Eastern Europe, as revealed by the land-use change approach

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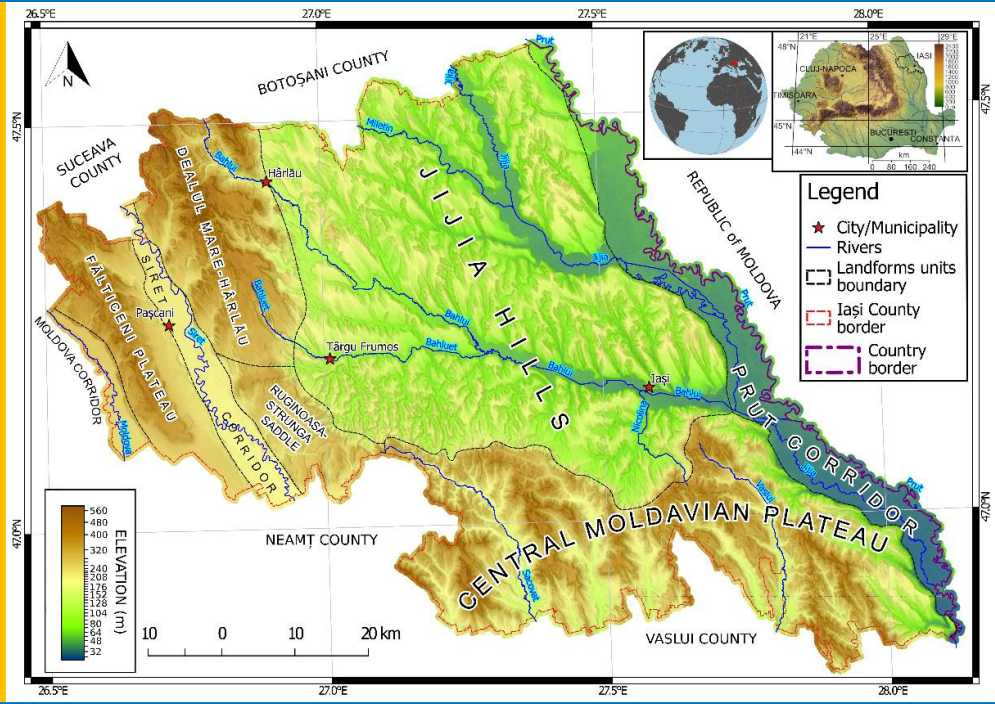
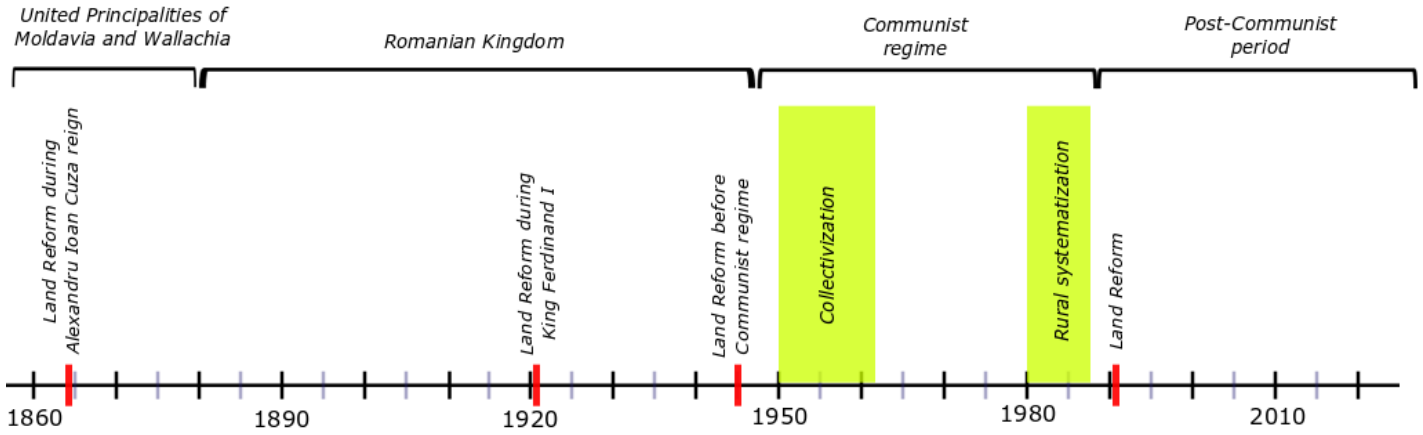
Introduction

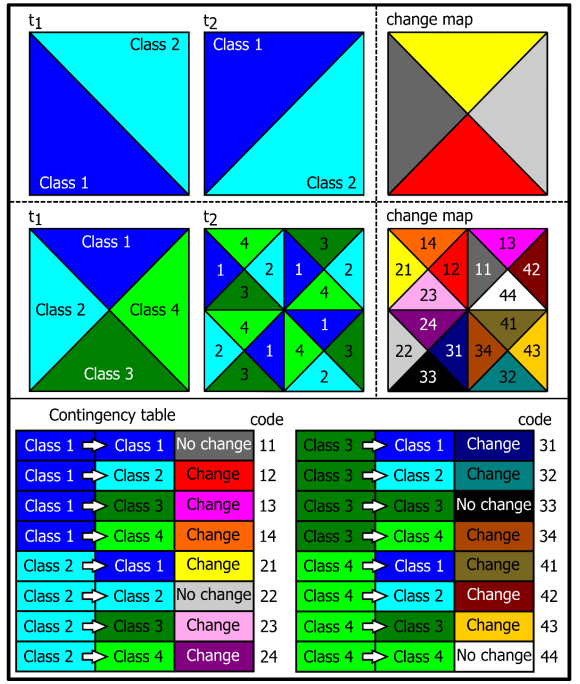


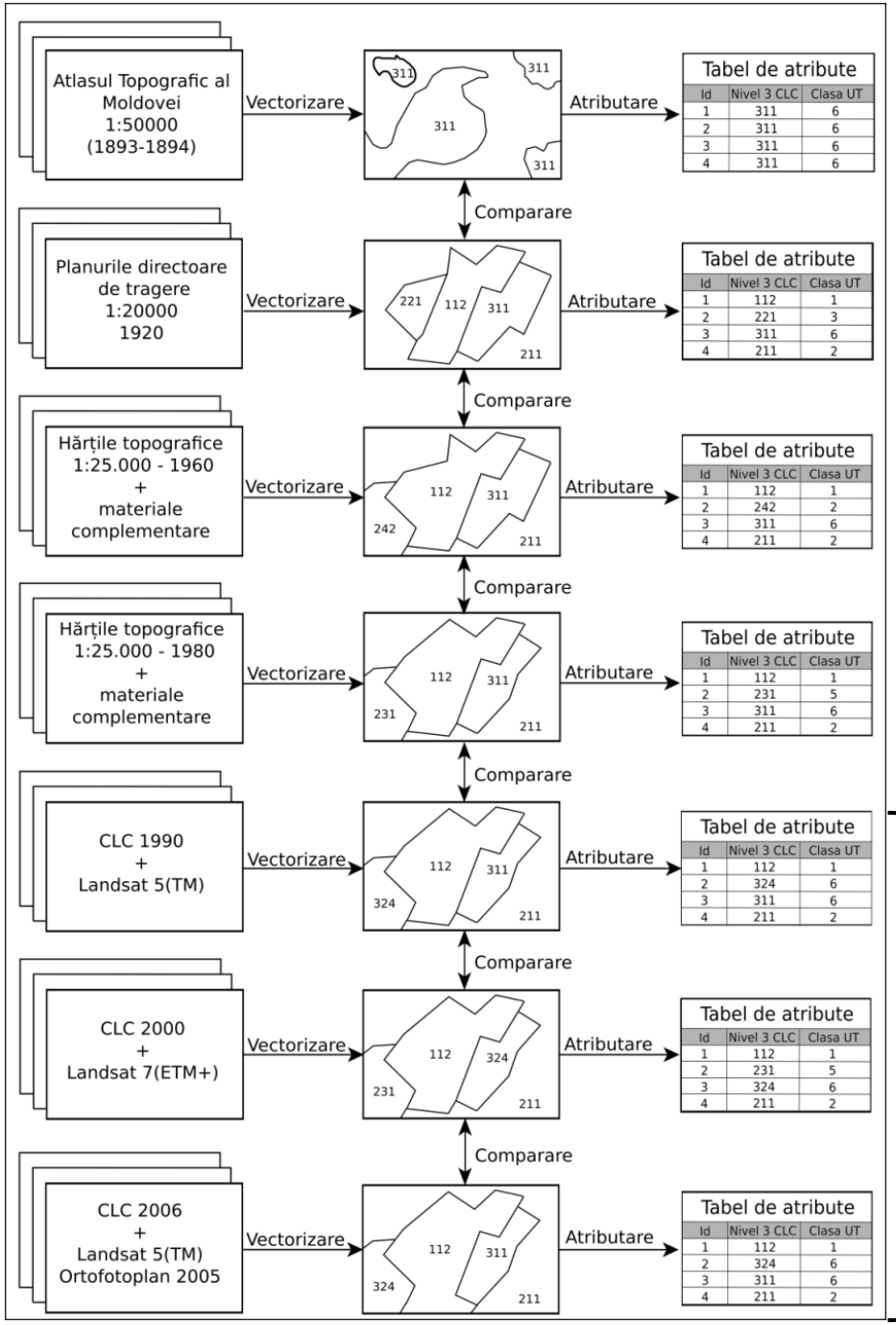


Materials and Methods

Data source	Type	Scale	Resolution	Field year
Moldavian Topographic Atlas, Cassini projection	Topographic map	1: 50 000	-	1893-1894
Army plans, Lambert-Cholesky projection	Topographic map	1:20 000	-	1916-1959
Topographic maps	Topographic map	1:25 000	-	1954-1959
	Topographic map	1:25 000	-	1972-1981
	Topographic map	1:5 000	-	1972-1989
	Topographic map	1:2 000-10 000	-	1980-1989
Aerial topographic surveys	Aerial imagery	-	0.25-0.5 m	1964, 1978, 1982
Corona KH-4B satellite imagery	Satellite imagery	-	1-25 m	(1960-1974)
Landsat 5 – 7 satellite imagery	Satellite imagery	-	15-30 m	(1970-2006)
Orthophoto-imagery	Aerial imagery	-	0.5 m	2005, 2008
World Imagery	Satellite and aerial imagery	-	one meter or better	update every 3-5 years
Corine Land Cover	Land-cover	1:100 000	25 ha, 100 m	1990, 2000, 2006

Change detection in the context of remote sensing (Singh, 2021) is defined as the **process of identifying differences in the state of an object or phenomenon by observing them at different times.** The process of detecting changes is a standard method used to analyze land-use dynamics. The most straightforward methodology involves the **raw local difference of pixels** (Tomlin, 1990) **between two rasters** (representing two different time intervals t1 and t2), using integers as codes for land-use categories and their combinations. Creating a **contingency matrix** for 1, 2, or more categories allows the computation of descriptive statistics and the overall fluxes between classes.





CLC Nivelul	CLC Nivelul 2	CLC Nivelul 3	Clase de utilizarea a terenului
1. Suprafețe Artificiale	1.1. Zone urbane	1.1.1. Spațiu urban continuu	(1) Terenuri locuite
		1.1.2. Spațiu urban discontinuu și spațiu rural	
	1.2. Unități industriale, comerciale și rețele de transport	1.2.1. Unități industriale sau comerciale	
		1.2.2. Rețea de căi de comunicație și terenuri asociate acestora	
		1.2.4. Aeroporturi	
	1.3. Zone miniere, în construcții sau cu deșeuri	1.3.1. Zone de extracție a minereurilor	
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	1.4. Zone artificiale neagricole acoperite cu vegetație	1.4.1. Zone urbane verzi	
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2. Zone Agricole	2.1. Terenuri arabile	2.1.1. Terenuri arabile neirigate	(2) Terenuri arabile
	2.2. Culturi permanente	2.2.1. Vii/Podgorii	(3) Terenuri viticole
		2.2.2. Livezi	(4) Terenuri pomicole
	2.3. Pășuni	2.3.1. Pășuni	(5) Terenuri cu pășuni
	2.4. Arii agricole heterogene	2.4.2. Zone de culturi complexe	(2) Terenuri arabile
		2.4.3. Terenuri predominant agricole în amestec cu vegetație naturală	
3. Păduri și zone semi-naturale	3.1. Păduri	3.1.1. Păduri de foioase	(6) Terenuri forestiere
		3.1.2. Păduri de conifere	
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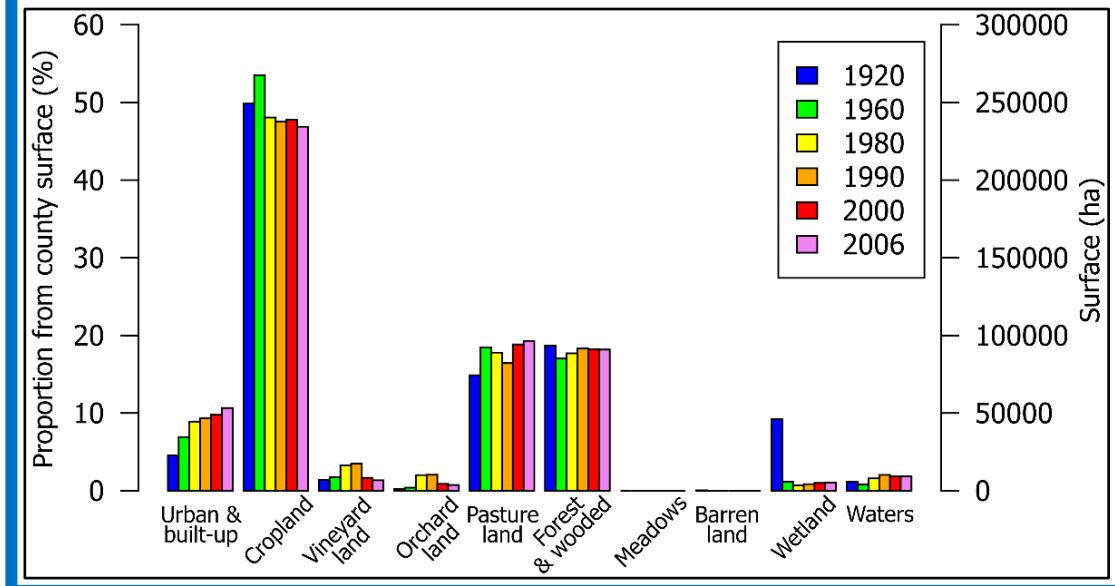
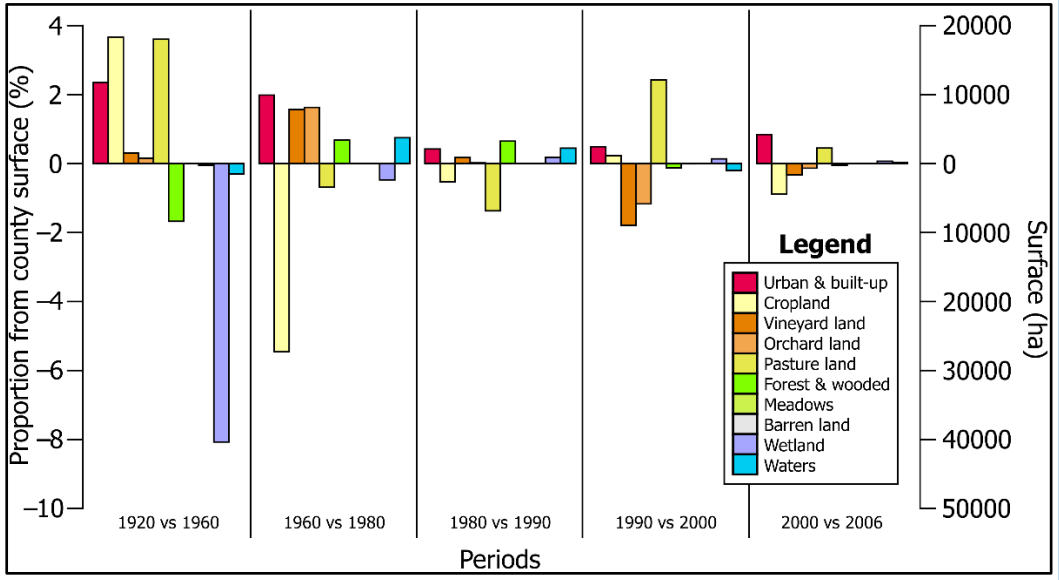
		3.2.4. Zone de tranziție cu arbuști (în general defrișate)	(6) Terenuri forestiere
	3.3. Spații deschise cu vegetație puțină sau deloc	3.3.1. Plaje, dune, renii	(8) Terenuri neproductive
4. Zone umede	4.1. Zone umede continentale	4.1.1. Mlaștini	(9) Terenuri cu mlaștini
5. Suprafețe acvatice	5.1. Ape continentale	5.1.1. Cursuri de apă	(10) Terenuri cu ape
		5.1.2. Acumulări de apă	



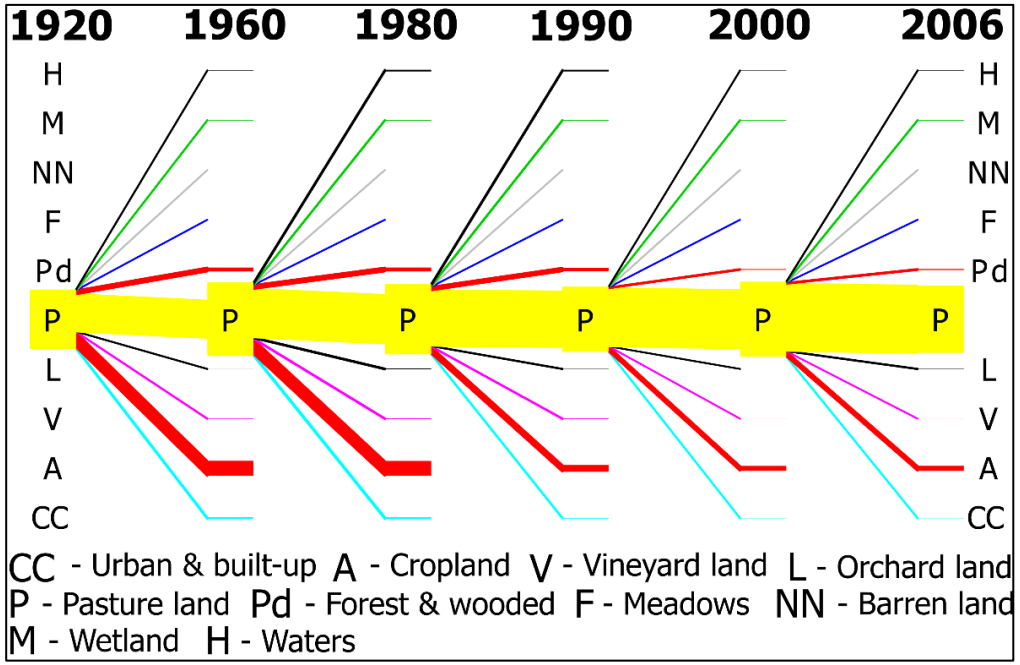


Dynamics of land use **as total sums** in Iaşi County for the 1920-2006 period

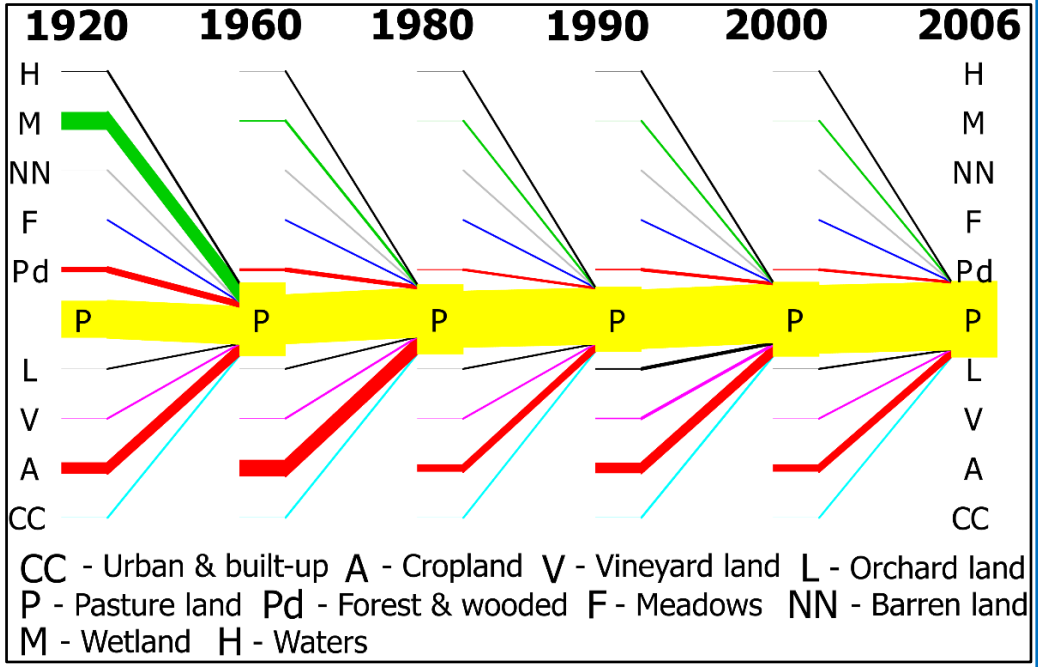
Dynamics of land use **as balance** in Iaşi County for the 1920-2006 period

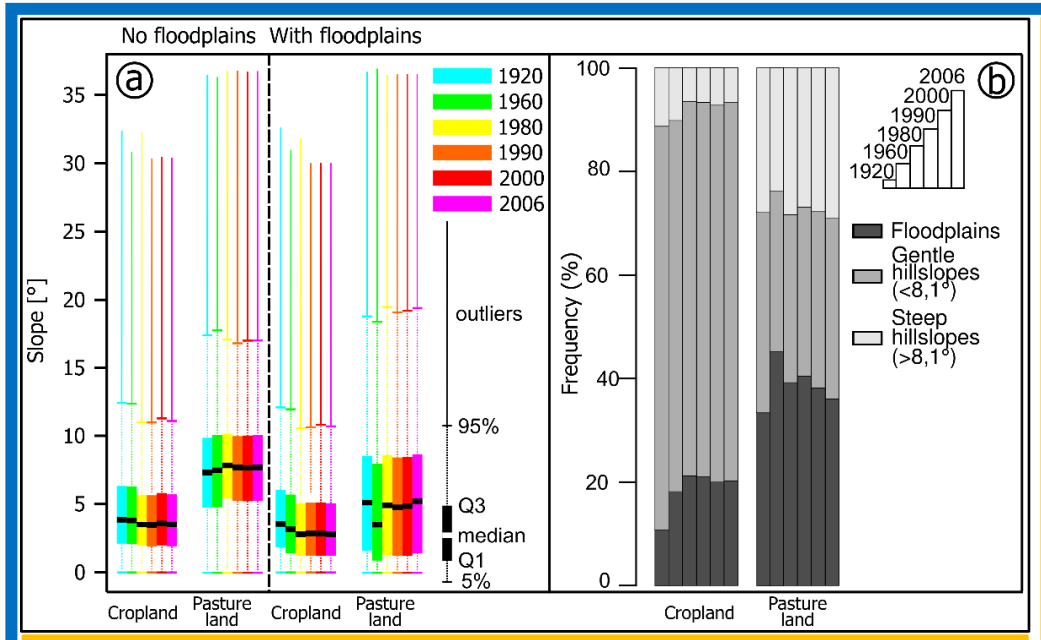
Results

The temporal fluxes of land use change **from pastures to other land-use types**



The temporal fluxes of land use change **from other land-use types to pastures**





The slope and landforms statistics by cropland and pasture land in Iași County (period 1920-2006).

Aerial imagery from **1959** (Buda village)

Aerial imagery from **1979** (Buda village)

Shading of LiDAR DEM showing the area of Buda village

Aerial imagery from **2018** (Buda village)

Aerial imagery from **2005** (Buda village)

Grassland ecosystems are one of the world's most commonly occurring land use types (Ali et al., 2016; Hardy et al., 2021). **Land use changes and modern climate variability** are seen by scientists as the main triggers of pasture dynamics worldwide (Afuye et al., 2022, 2021; Jong et al., 2012; Tucker et al., 2001).

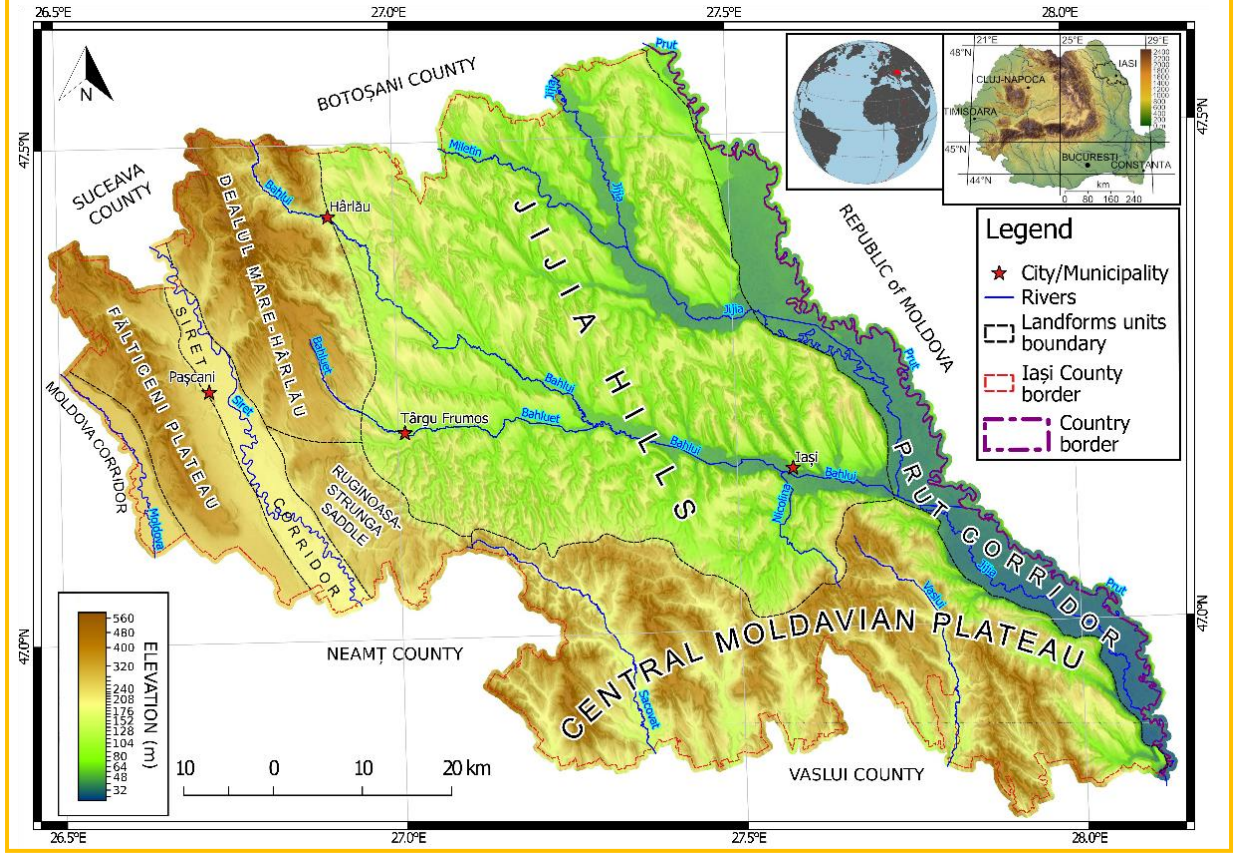
Land use and land cover are shaped under the influence of two broad sets of forces - human needs and environmental characteristics and processes (Briassoulis, 2020).

The **historical approach** to land-use dynamics is both broad and complex. The importance of the subject is evident due to the long list of real and perceived controversies that can take part in land-use change decisions, the most prominent being **land reforms**. The extent of land-use change also varies depending on the analyzed period. The size and place of human activities on the land surface have accelerated over the past 300 years (Briassoulis, 2020; Lambin et al., 2006). The majority of the land has a high degree of anthropization after 1960, and already transformed lands have been managed more intensively to increase the yield of agricultural and forest products (Winkler et al., 2021).

The main objective of this study is to **analyze the land use in Iaşi County (NE Romania), starting with the 20th century**, based on **cartographic materials, satellite and aerial images**, and other available databases, focusing on **pasture land**. Throughout history, grasslands, especially pastures, have been used to produce **food for livestock, fiber, and fuel** (Kemp and Michalk, 2007). The conversion of forests to livestock pastures or any other natural ecosystem into agricultural land has been frequently identified during the development of human civilization (Humphries, 1998; Rodriguez Eraso et al., 2013) as a primary driver of progress since the agricultural revolution that followed the Neolithic period (Winter-Schuh et al., 2018; Kamjan et al., 2020; Pizziolo et al., 2021). Simultaneously, this **conversion increased erosion and generated land degradation** (Cotler and Ortega-Lorrocea, 2006, Gebremedhin, 2017) in some areas, especially dryer regions such as the Moldavian Plateau in eastern Romania.

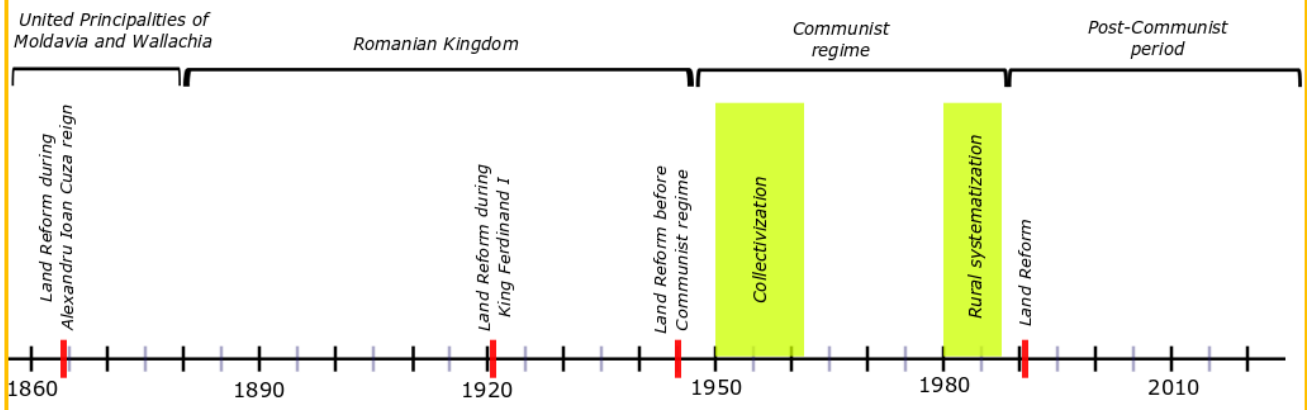
The geographic localization of the study area and the general physiography:

- Is located in northeastern Romania in the central part of the Moldavian Plateau.
- Hilly area with a monoclinal geological structure, and repetitive cuesta landforms.
- Iași County is a dry area with average multiannual temperatures of 9.4°C.



Historical events with impact on land–use evolution:

- The administrative-territorial organization of Iași County has been relatively stable over the last 300 years.
- The population evolution data based on the census indicate a continuous increase of inhabitants, from 300,000 in 1912 to 976,586 in 2021.
- Transition from a subsidence economy to a capitalist economy during inter-war.
- Predominance of small properties, which fragmented from year to year.
- During the communist period (1946–1989), the Romanian economy was nationalized.
- After the 1980s, the standard of living dropped quite significantly, and Romania entered a stage of economic underdevelopment.
- One of the major changes was the restitution to the previous owners of collectivized agricultural lands.
- The first period, from 1990 to 2000, was characterized by a general economic decline and land abandonment.



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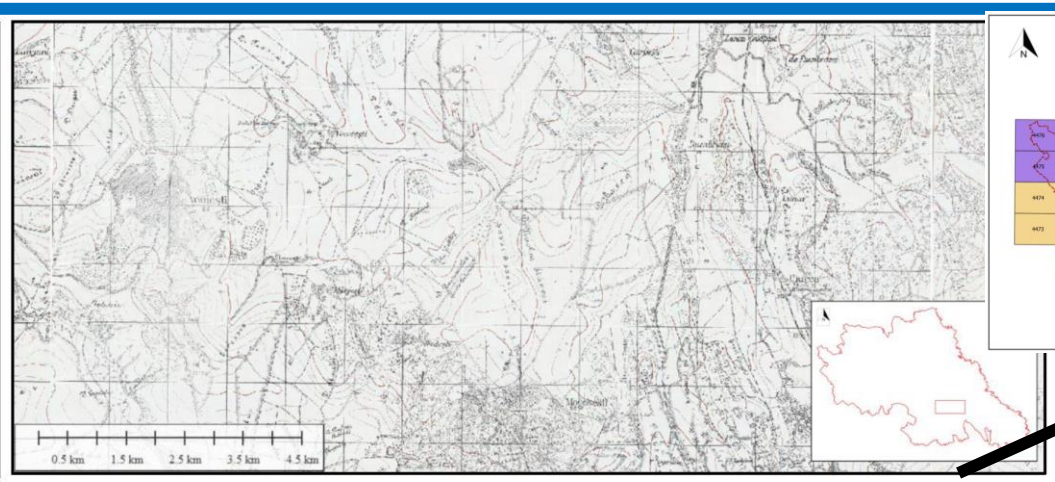

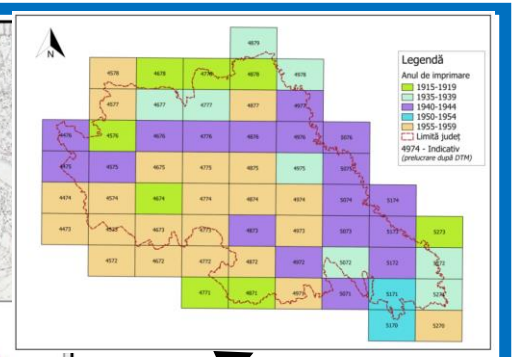

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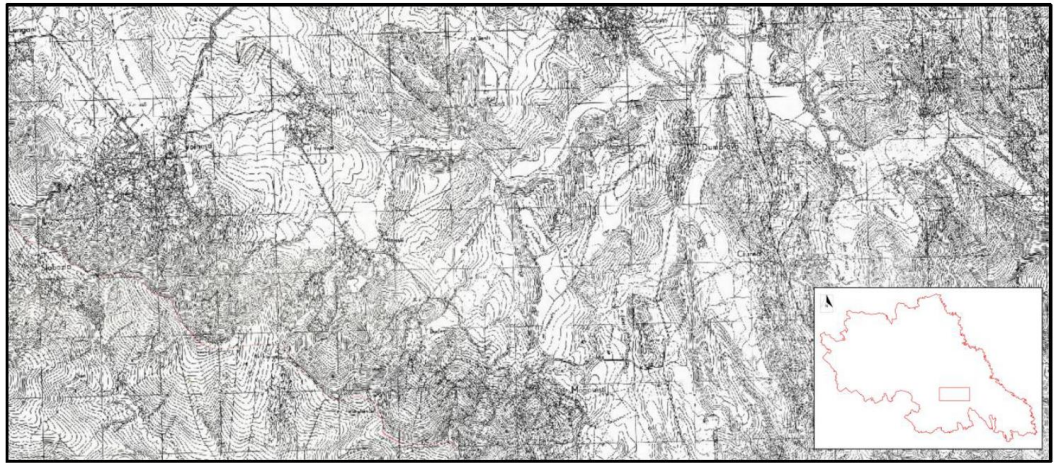

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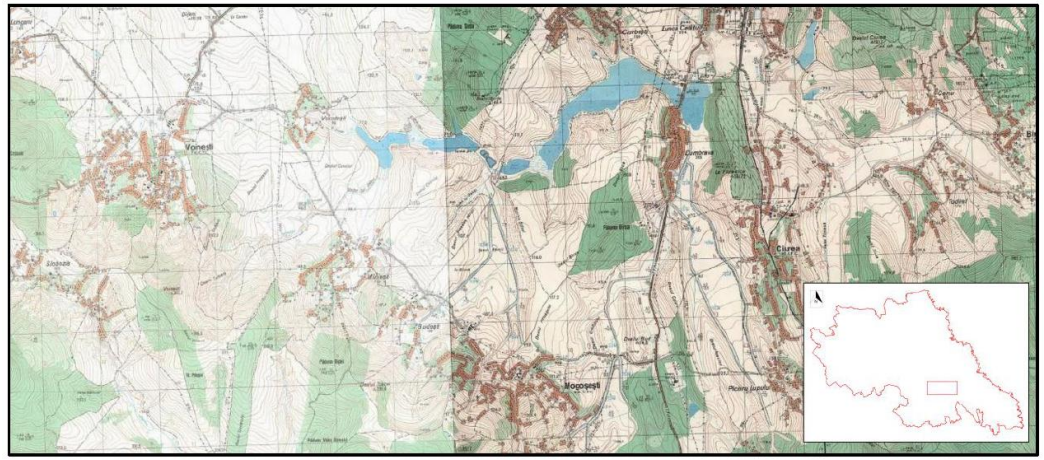

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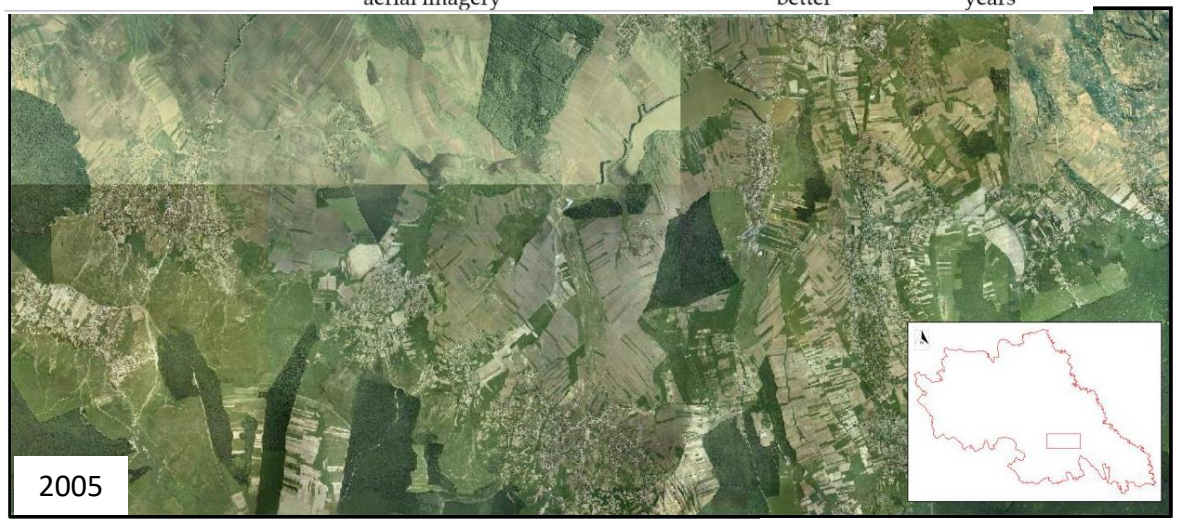

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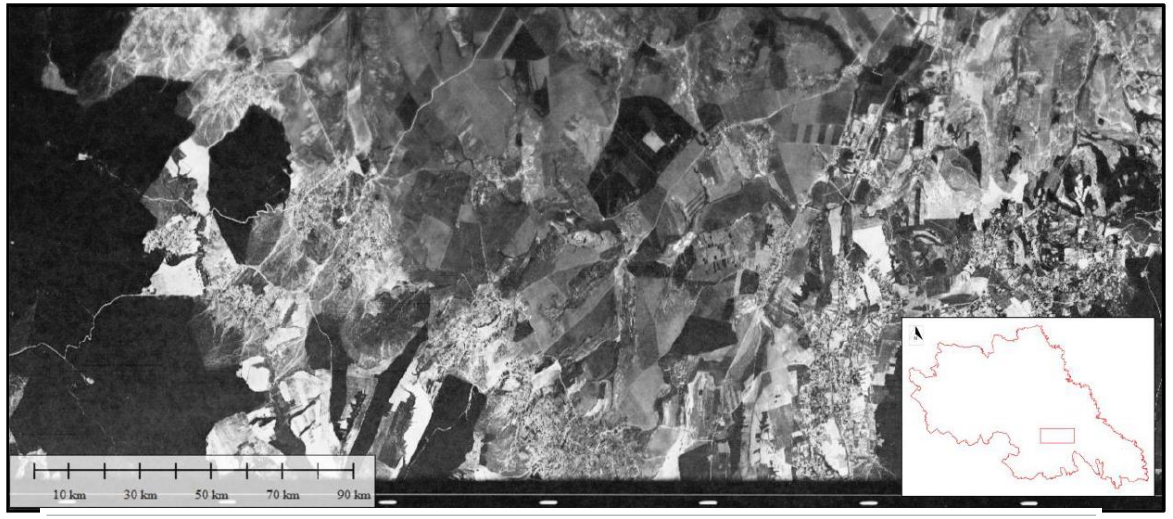
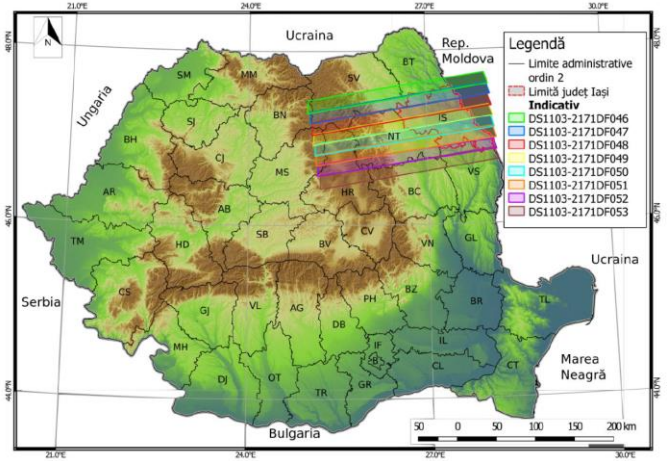
Orthophoto-imagery	Aerial imagery	-	0.5 m	2005, 2008

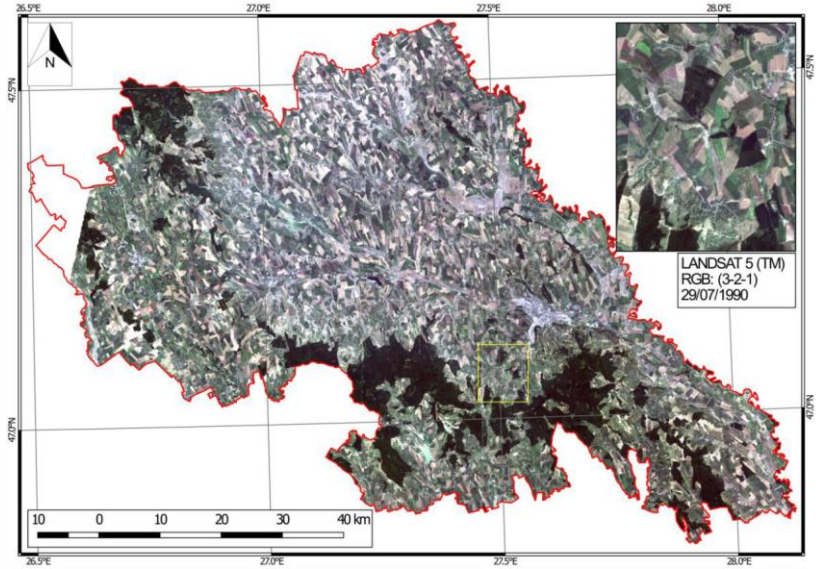


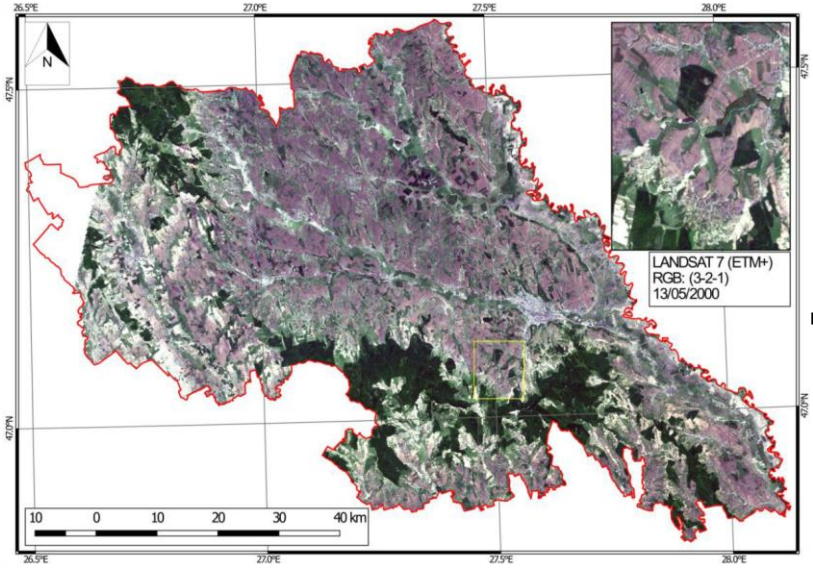
Data source	Type	Scale	Resolution	Field year
Corona KH-4B satellite imagery	Satellite imagery	-	1-25 m	(1960-1974)

The footprint of CORONA imagery on Iași County area

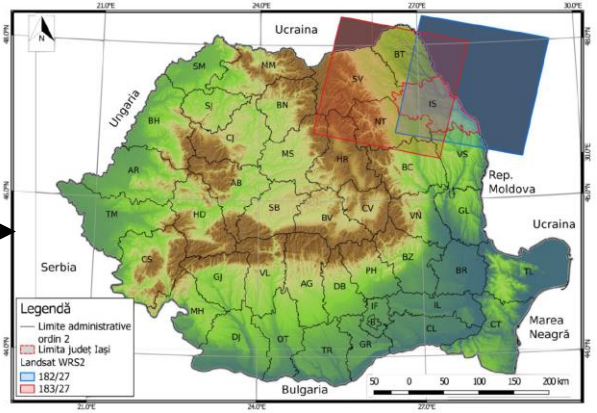


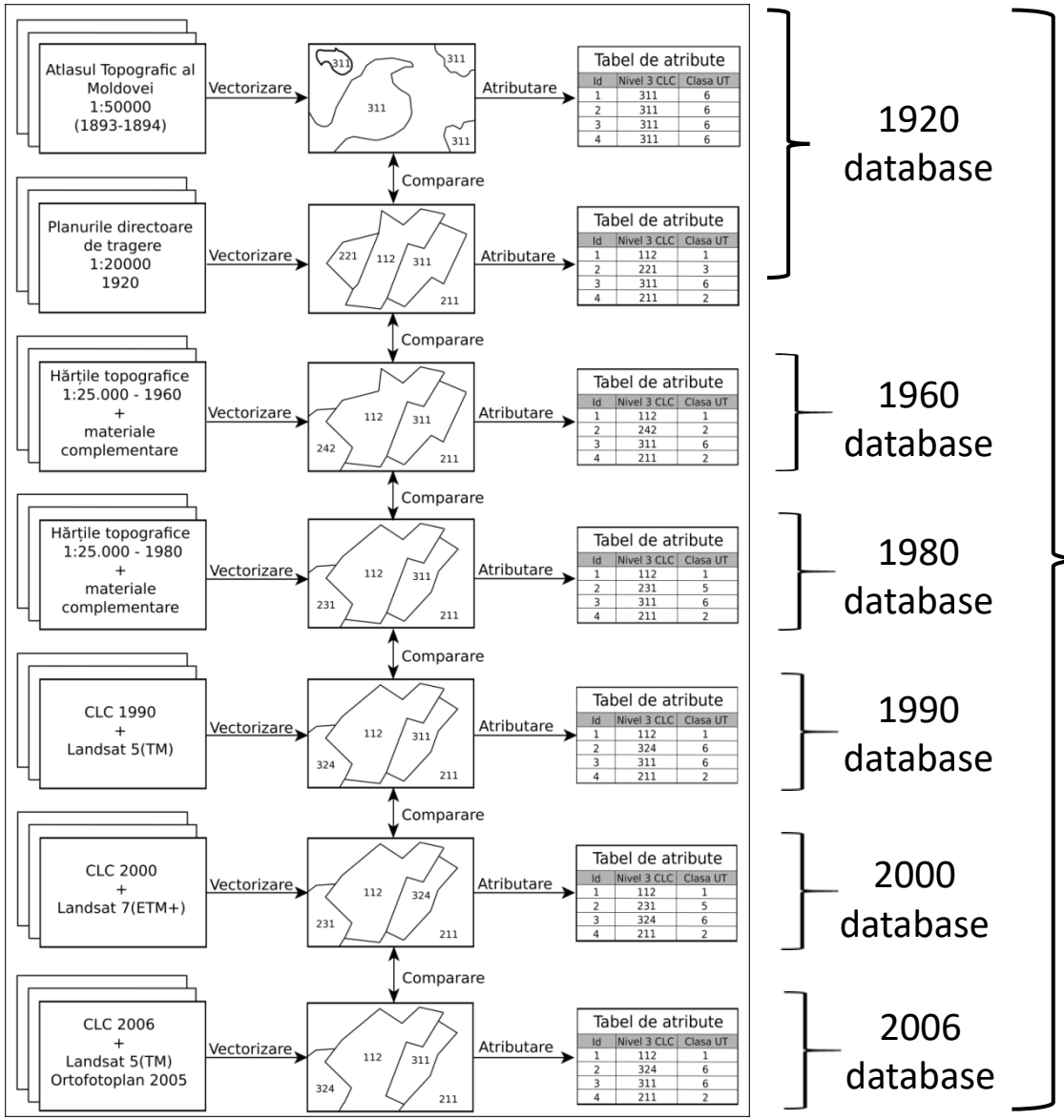
Data source	Type	Scale	Resolution	Field year
Landsat 5 – 7 satellite imagery	Satellite imagery	-	15-30 m	(1970-2006)





The footprint of LANDSAT imagery on Iași County area





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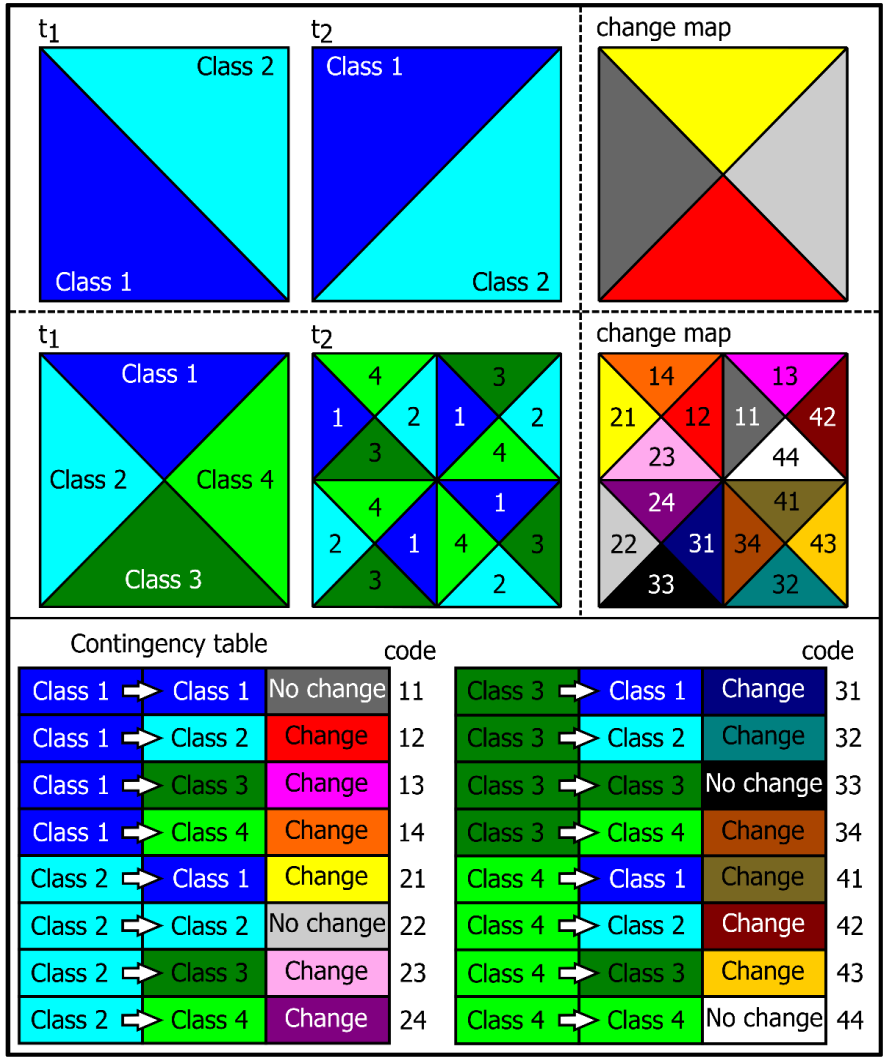
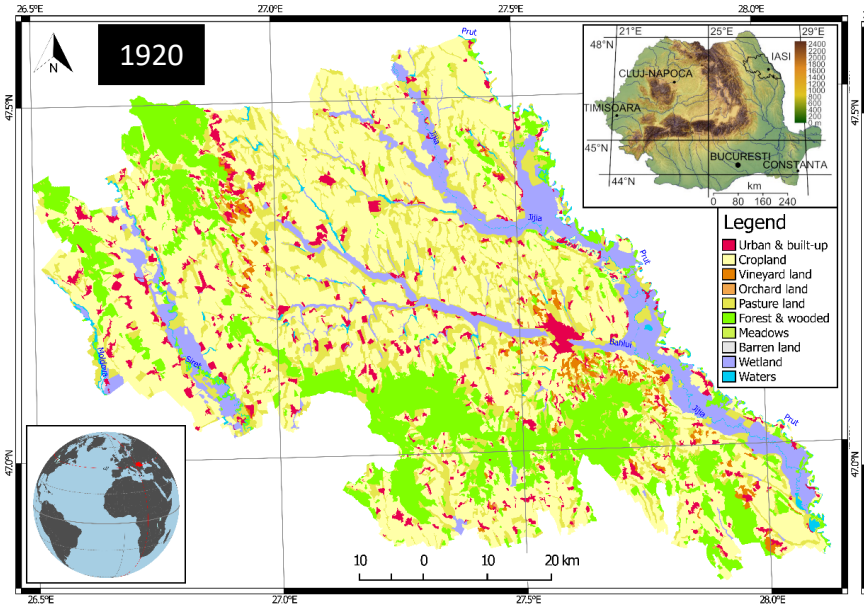
Change detection in the context of remote sensing (Singh, 2021) is defined as the **process of identifying differences in the state of an object or phenomenon by observing them at different times.** Change detection often involves **comparing two satellite images** or two aerial photographs with different acquisition data covering the same area of interest (Lu et al., 2010). **The process of detecting changes is a standard method used to analyze land-use dynamics**.

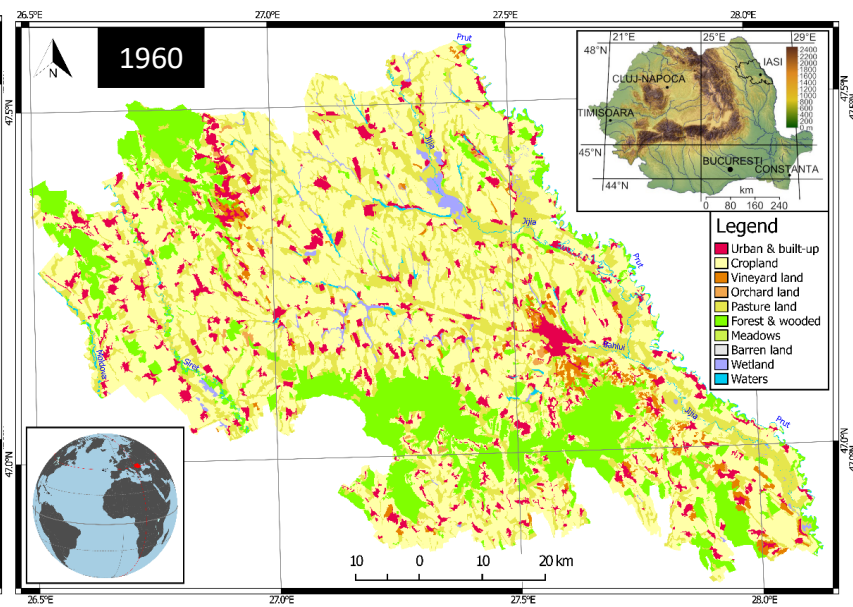
The most straightforward methodology involves the **raw local difference of pixels** (Tomlin, 1990) **between two rasters** (representing two different time intervals t1 and t2), using integers as codes for land-use categories and their combinations. Creating a **contingency matrix** for 1, 2, or more categories allows the computation of descriptive statistics and the overall fluxes between classes. The spatial results can be shown by styling the resulting raster with combination codes. **This approach is implemented in SAGA GIS (Conrad et al., 2015) as the Confusion Matrix (Two Grids) module from Imagery/Classification tool library. We used the R stat** (R Core Team, 2019) **coding environment coupled with the raster** (Hijmans, 2022) **and RSAGA** (Brenning et al., 2018) **packages to filter the spatial results for the generalized classes of no change, positive and negative, and to derive Sankey plots** (Cuba, 2015).

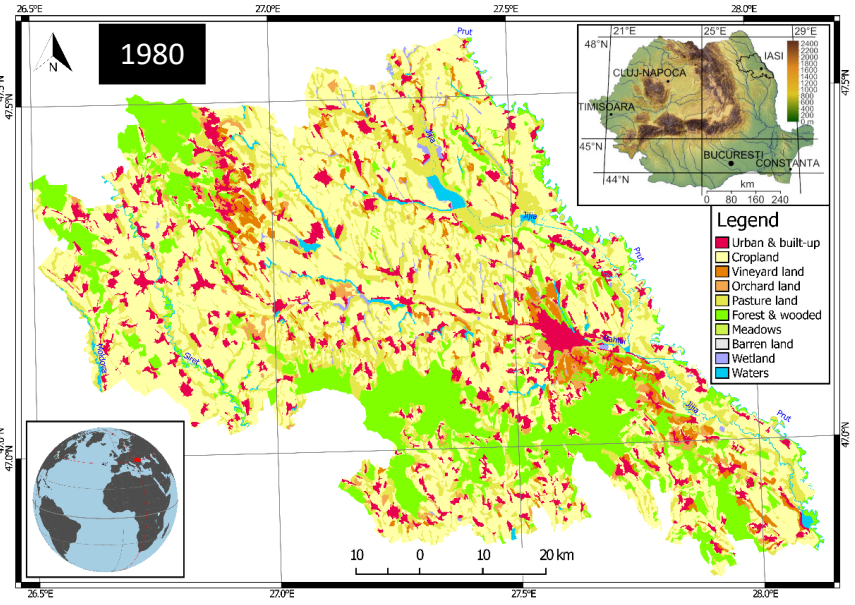
The presented change-detection approach allows us to assess the gains and losses between land-use/land-cover types in a region over several periods and to provide the following information (Lu et al., 2010): (i) **change of area and type of change**, (ii) **spatial distribution of modified classes**, (iii) **the trajectory of the changes of the land-use classes**, and (iv) **the evaluation of the accuracy of change-detection results**.



Two and multiple classes' computational change detection in the raster approach for two different times t1 and t2


1920
Legend
Urban & built-up
Cropland
Vineyard land
Orchard land
Pasture land
Forest & wooded
Meadows
Barren land
Wetland
Waters
CLUJ-NAPOCA
TIMISOARA
BUCURESTI
CONSTANTA
IASI
10 0 10 20 km


1960
Legend
Urban & built-up
Cropland
Vineyard land
Orchard land
Pasture land
Forest & wooded
Meadows
Barren land
Wetland
Waters
CLUJ-NAPOCA
TIMISOARA
BUCURESTI
CONSTANTA
IASI
10 0 10 20 km


1980
Legend
Urban & built-up
Cropland
Vineyard land
Orchard land
Pasture land
Forest & wooded
Meadows
Barren land
Wetland
Waters
CLUJ-NAPOCA
TIMISOARA
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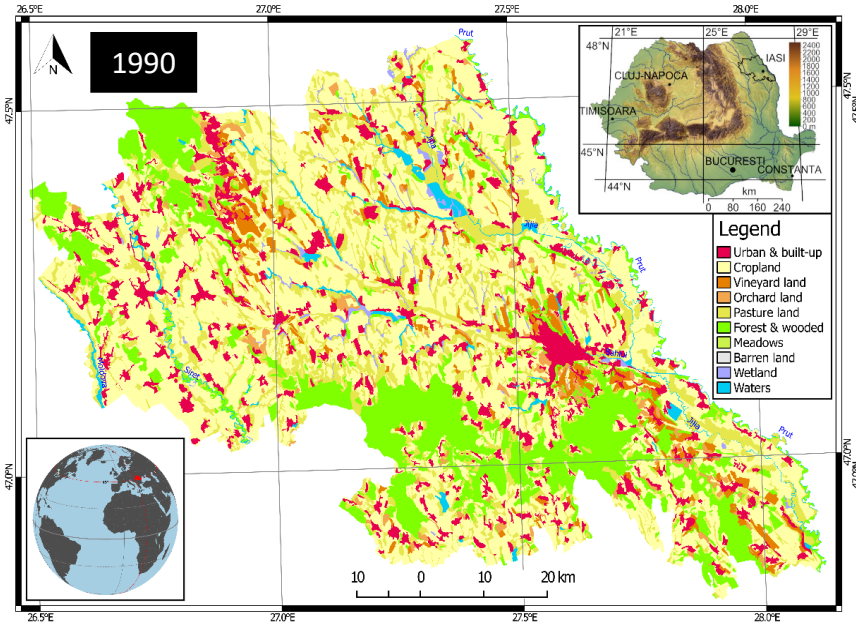
IASI
10 0 10 20 km


1990
Legend
Urban & built-up
Cropland
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Barren land
Wetland
Waters
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TIMISOARA
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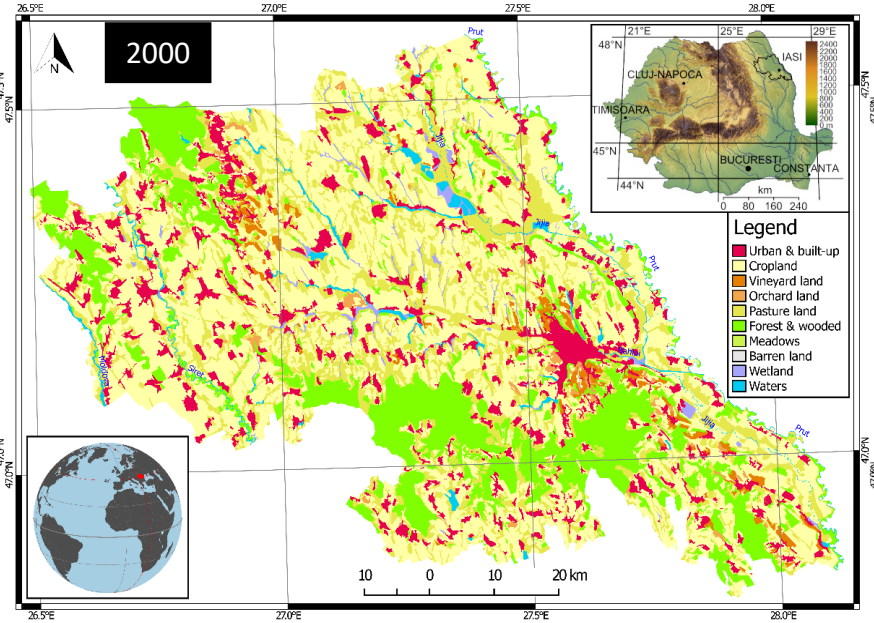
CONSTANTA
IASI
10 0 10 20 km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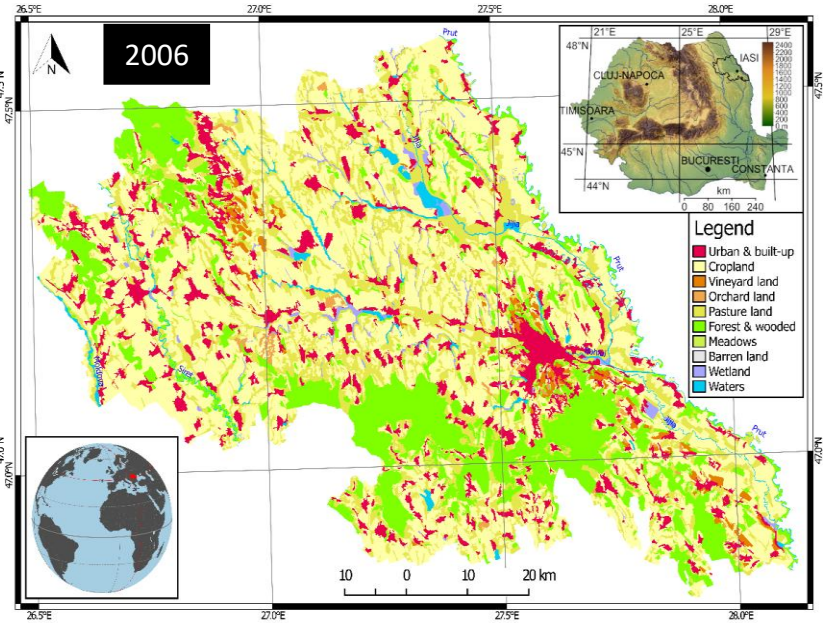
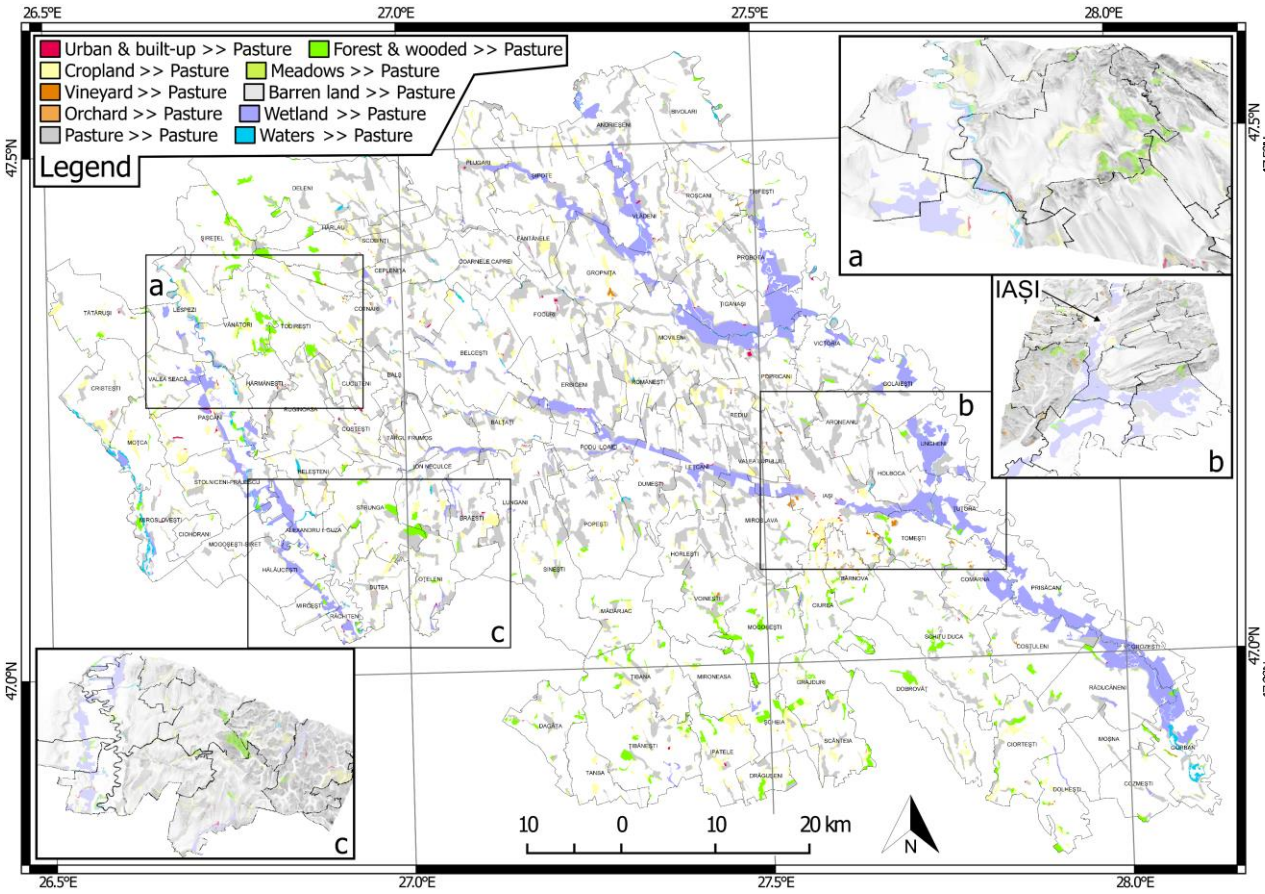
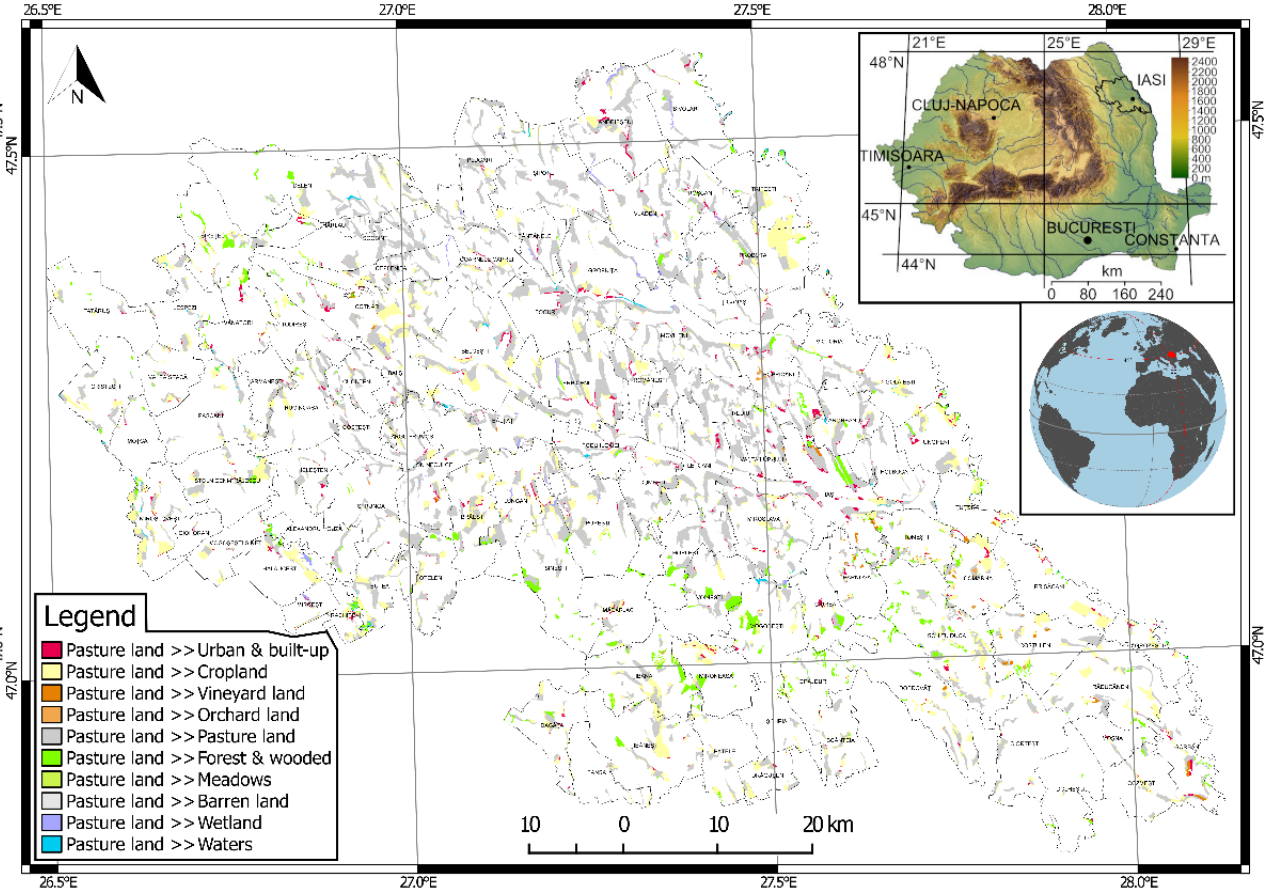
Orchard land
Pasture land
Forest & wooded
Meadows
Barren land
Wetland
Waters
CLUJ-NAPOCA
TIMISOARA
BUCURESTI
CONSTANTA
IASI
10 0 10 20 km

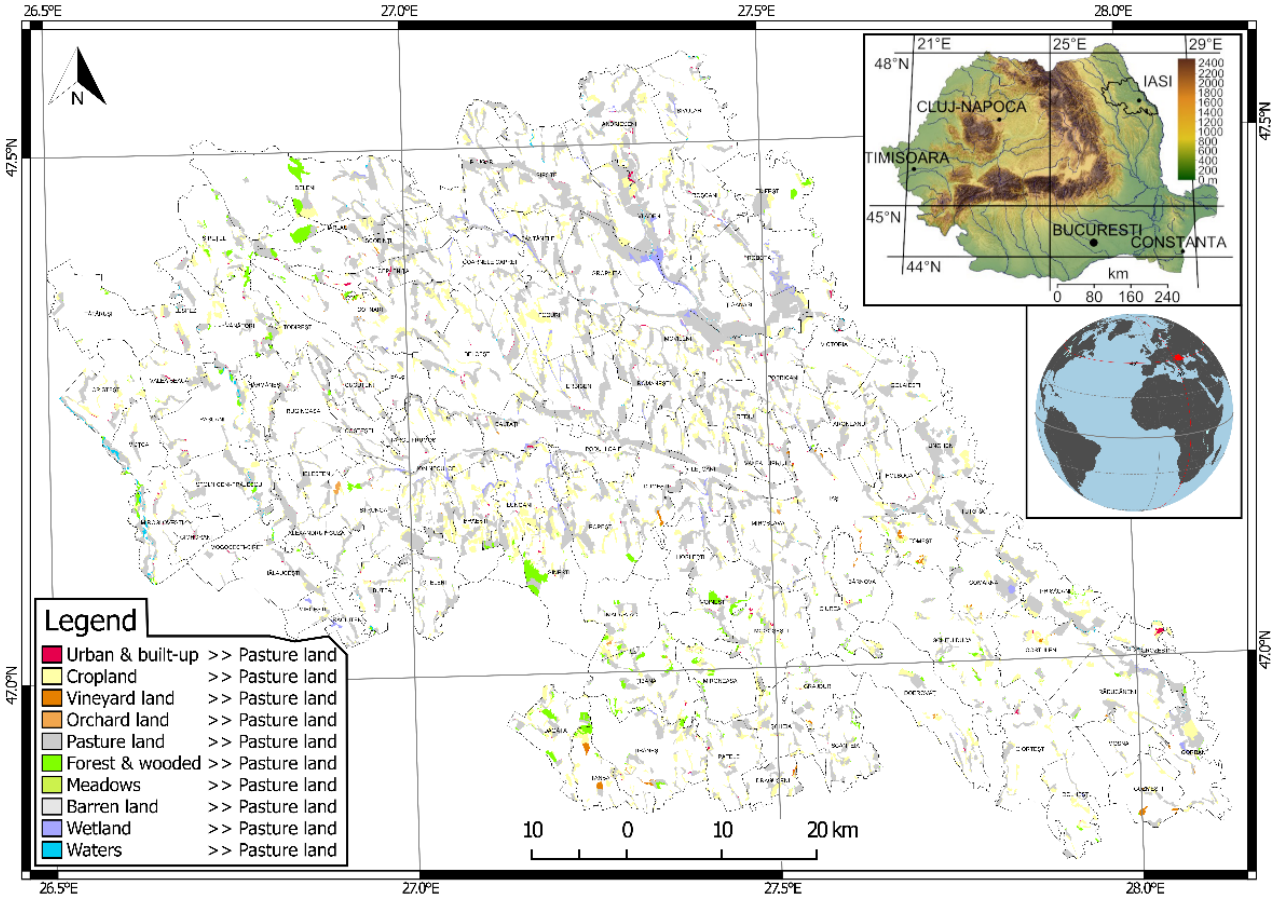

2006
Legend
Urban & built-up
Cropland
Vineyard land
Orchard land
Pasture land
Forest & wooded
Meadows
Barren land
Wetland
Waters
CLUJ-NAPOCA
TIMISOARA
BUCURESTI
CONSTANTA
IASI
10 0 10 20 km



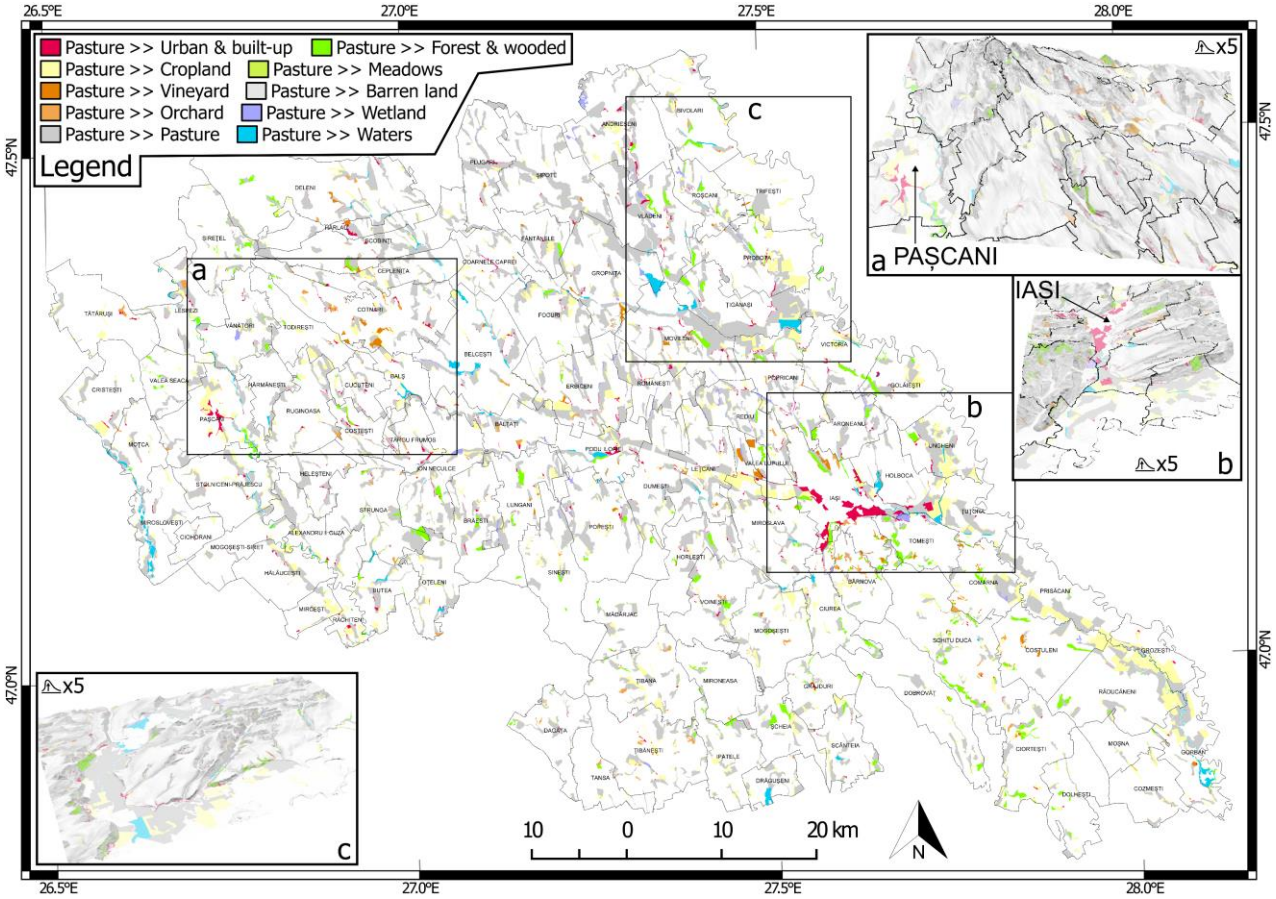
Pasture lands converted from other land use types for **1920-1960** in Iași County



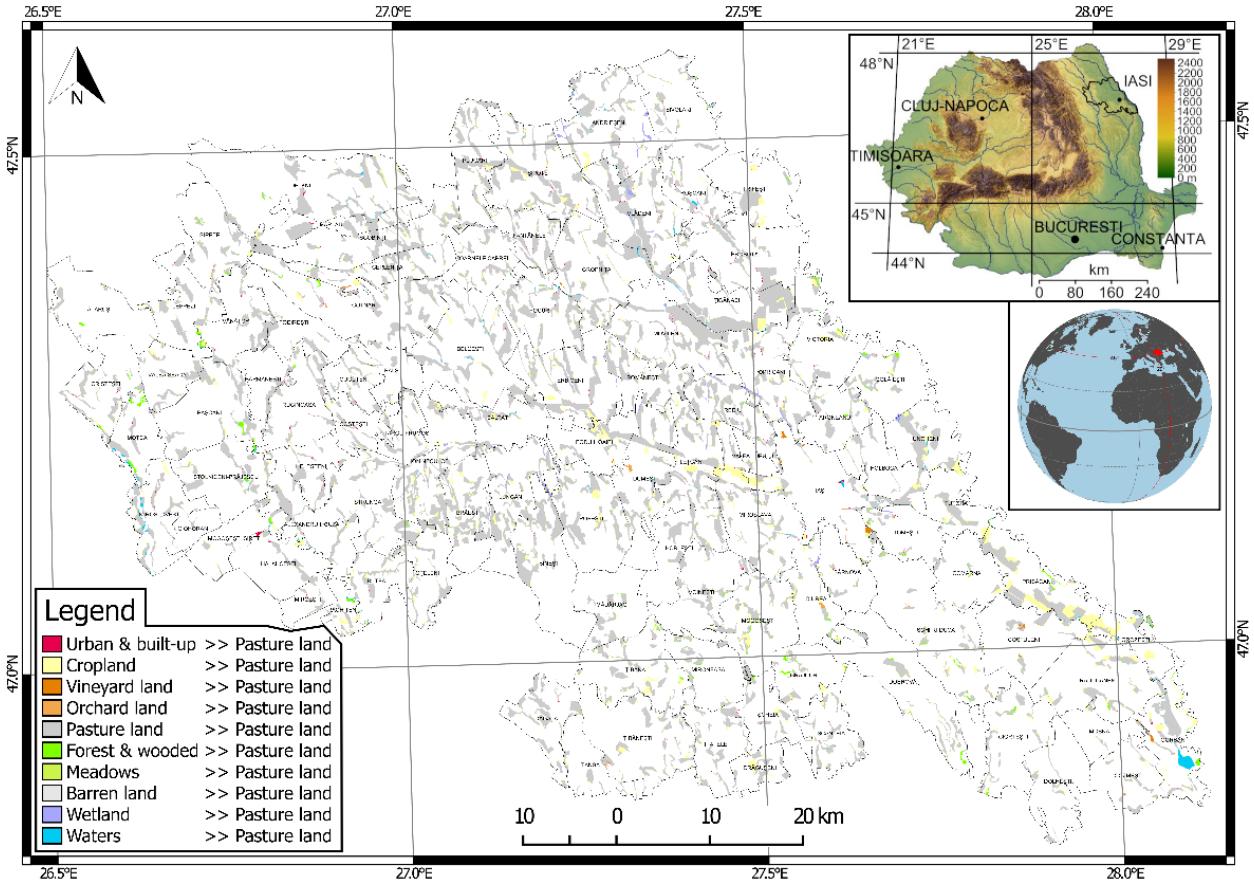
Pasture lands converted to other land use types for **1920-1960** in Iași County



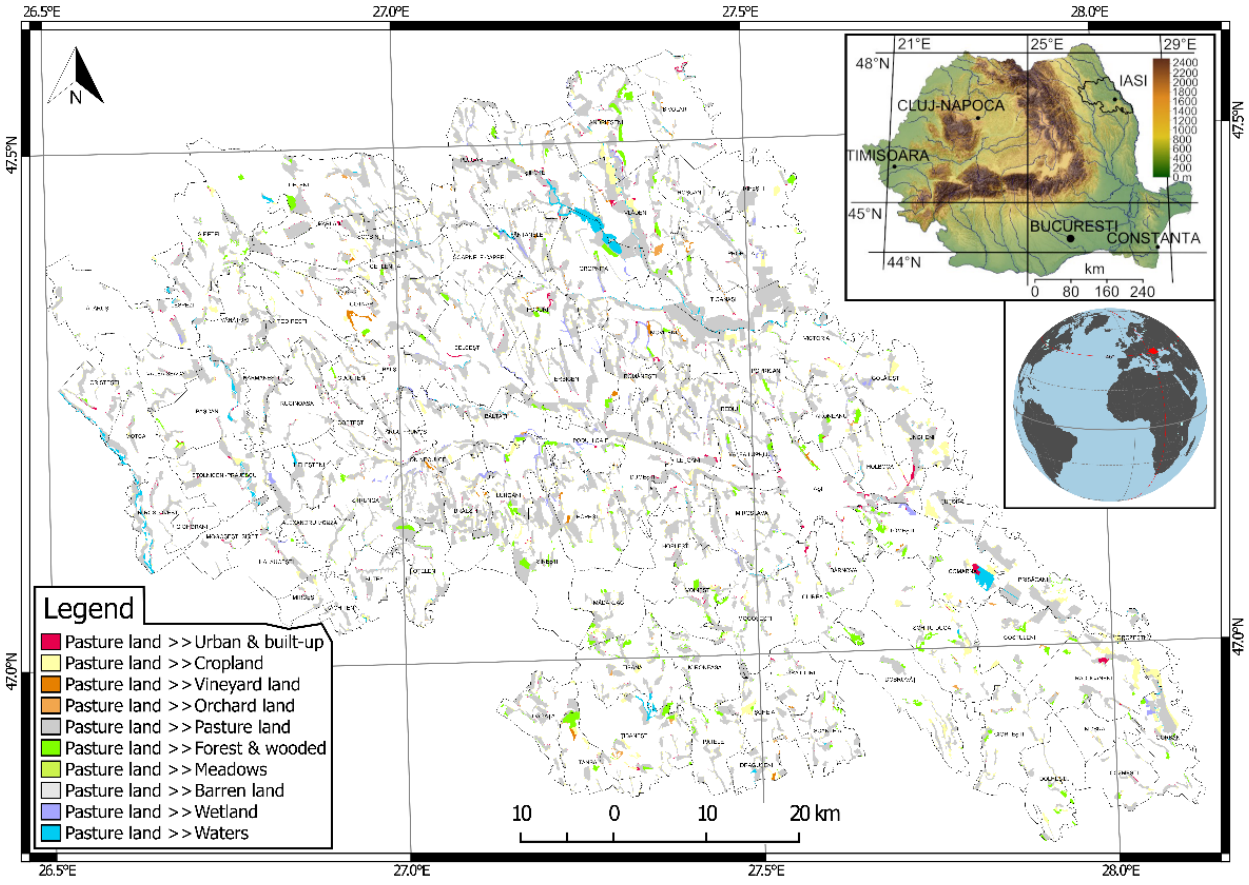
Pasture lands converted from other land use types for **1960-1980** in Iași County



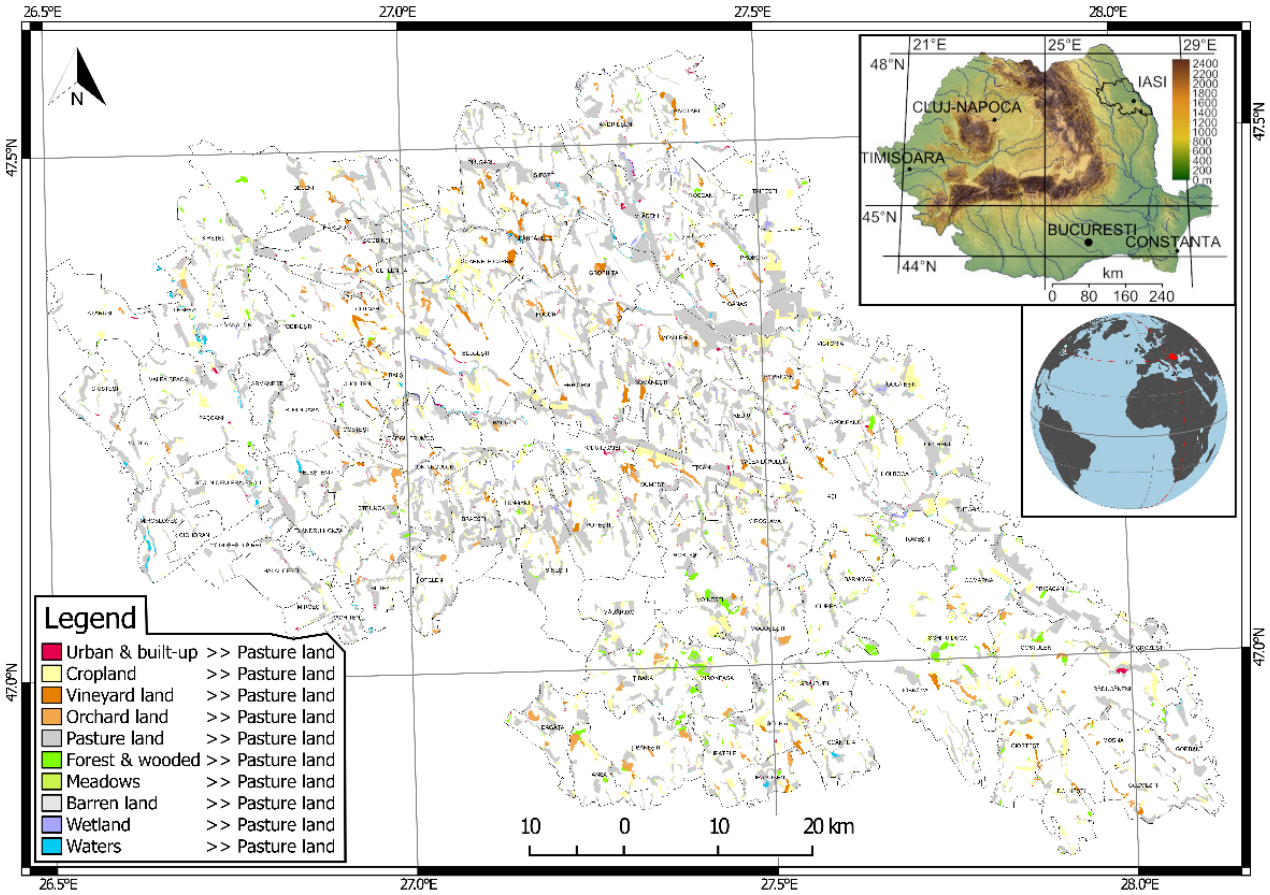
Pasture lands converted to other land use types for **1960-1980** in Iași County



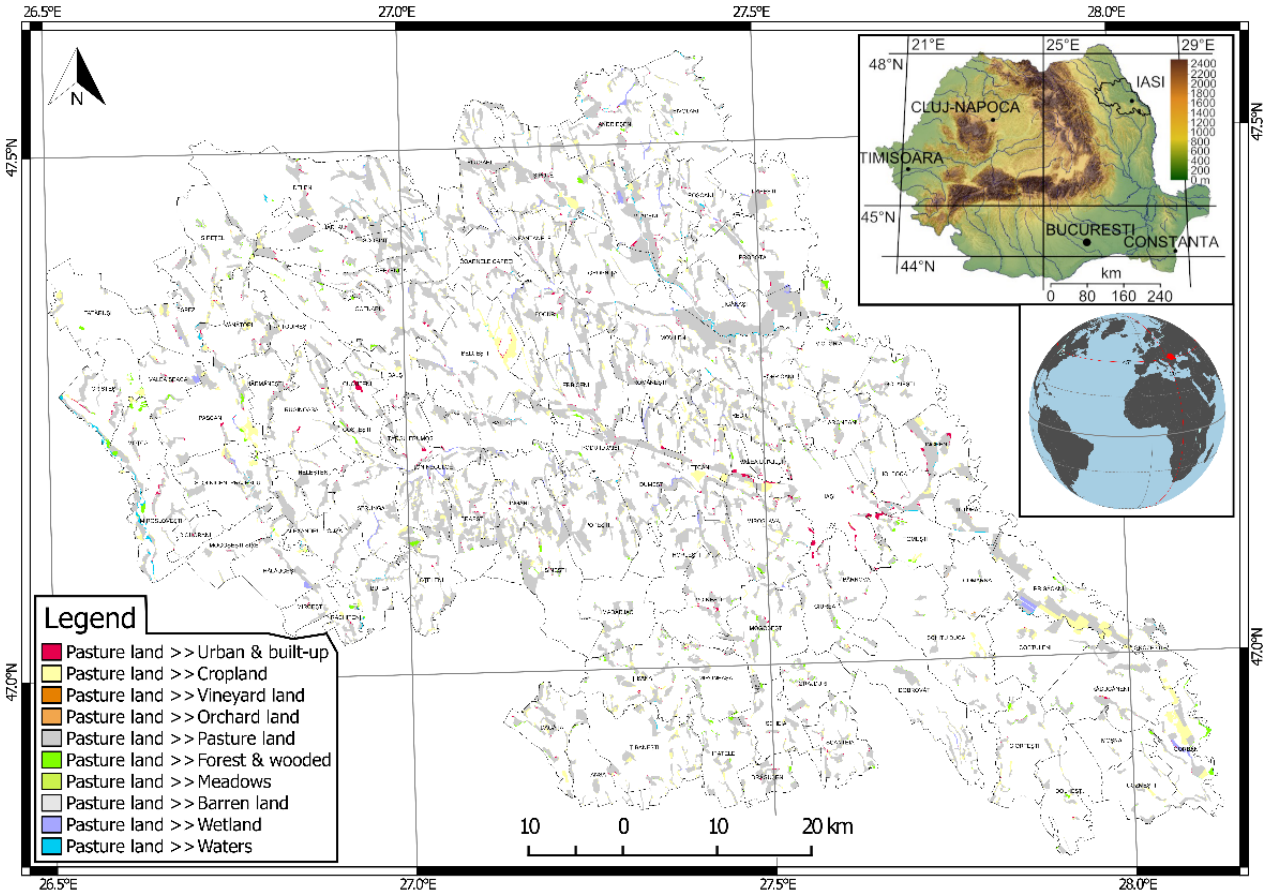
Pasture lands converted from other land use types for **1980-1990** in Iași County



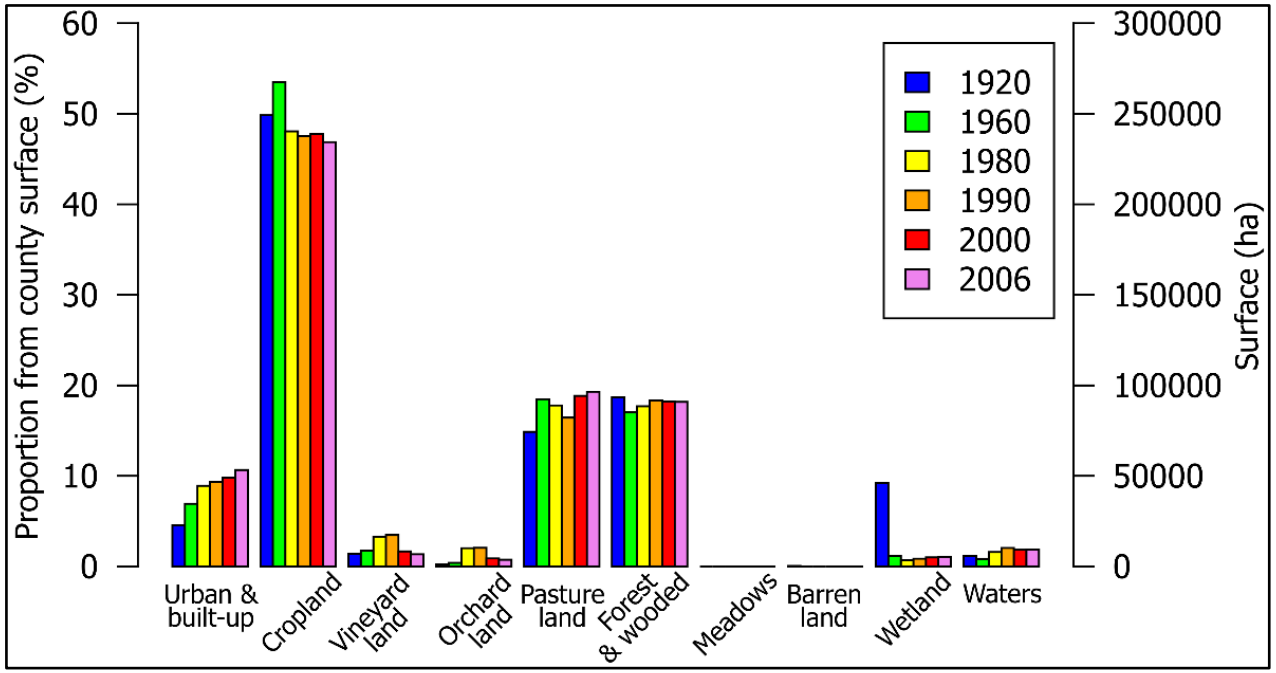
Pasture lands converted to other land use types for **1980-1990** in Iași County



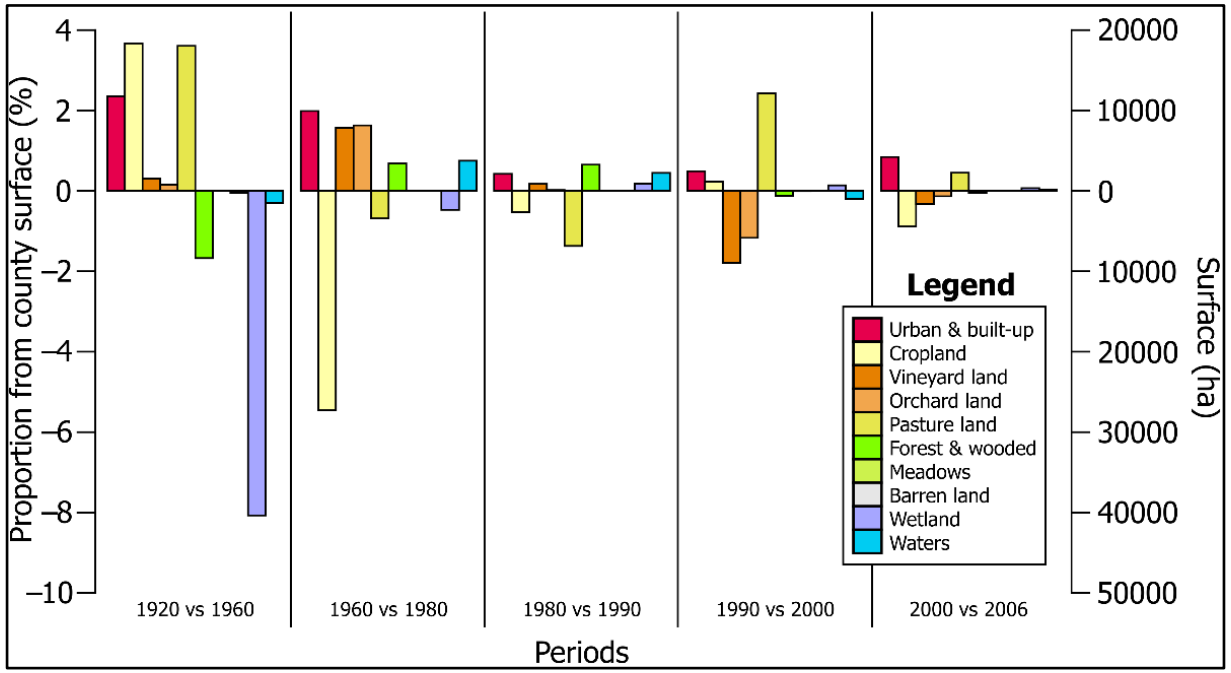
Pasture lands converted from other land use types for **1990-2006** in Iași County



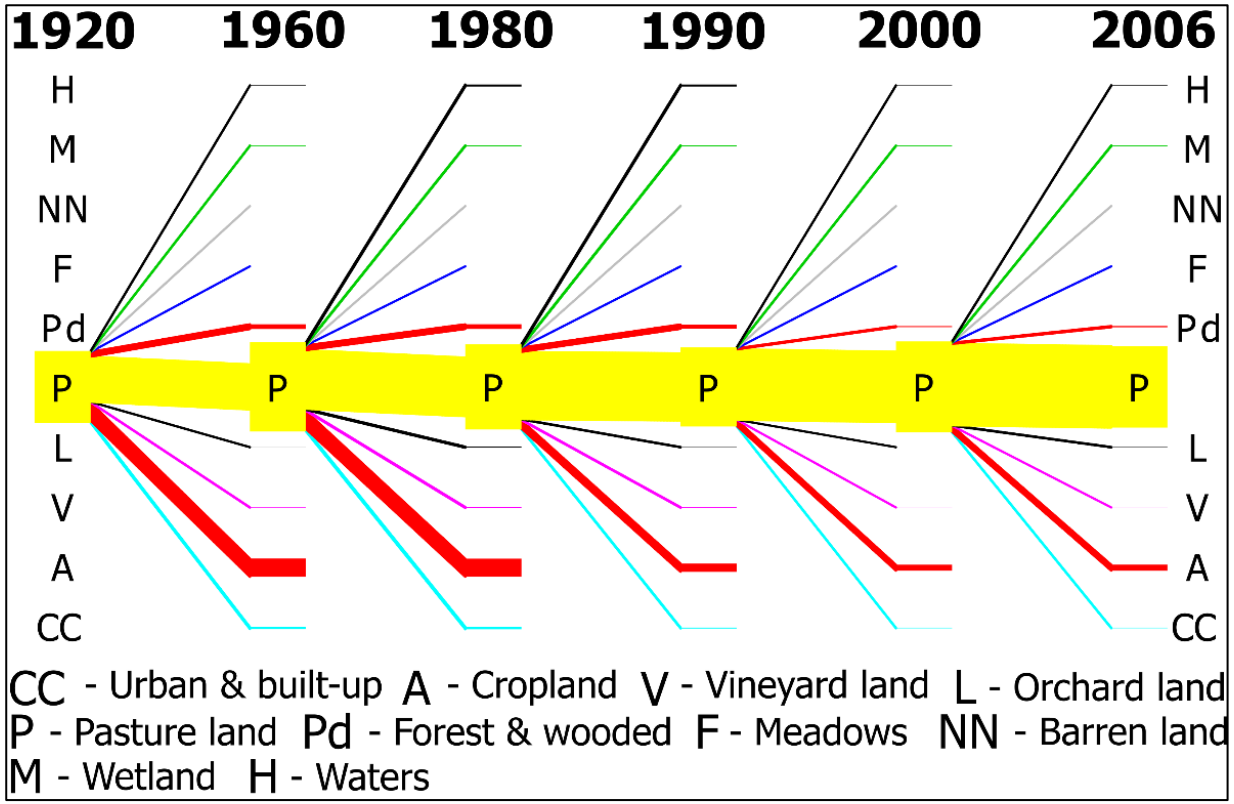
Pasture lands converted to other land use types for **1990-2006** in Iași County



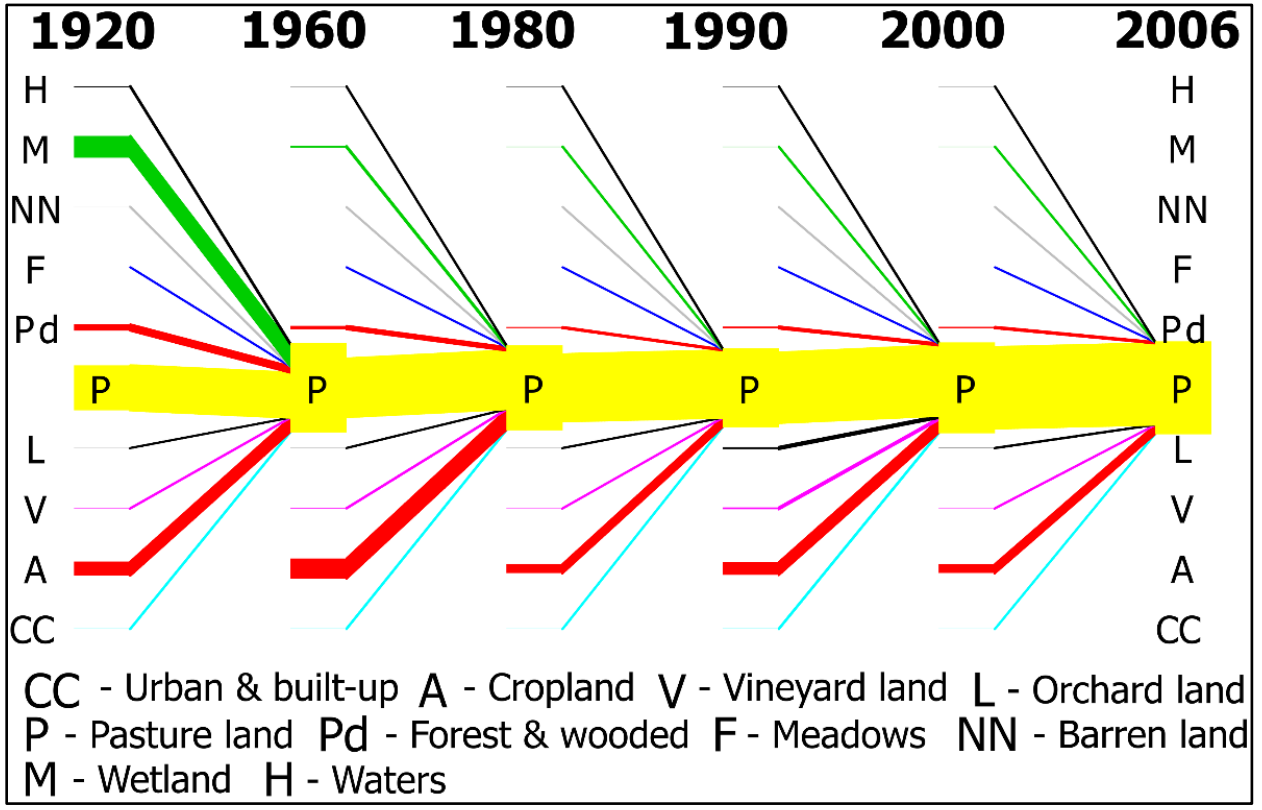
Dynamics of land use **as total sums** in Iaşi County for the 1920-2006 period (percent of present-day county surface of 5477.411125 km^2)



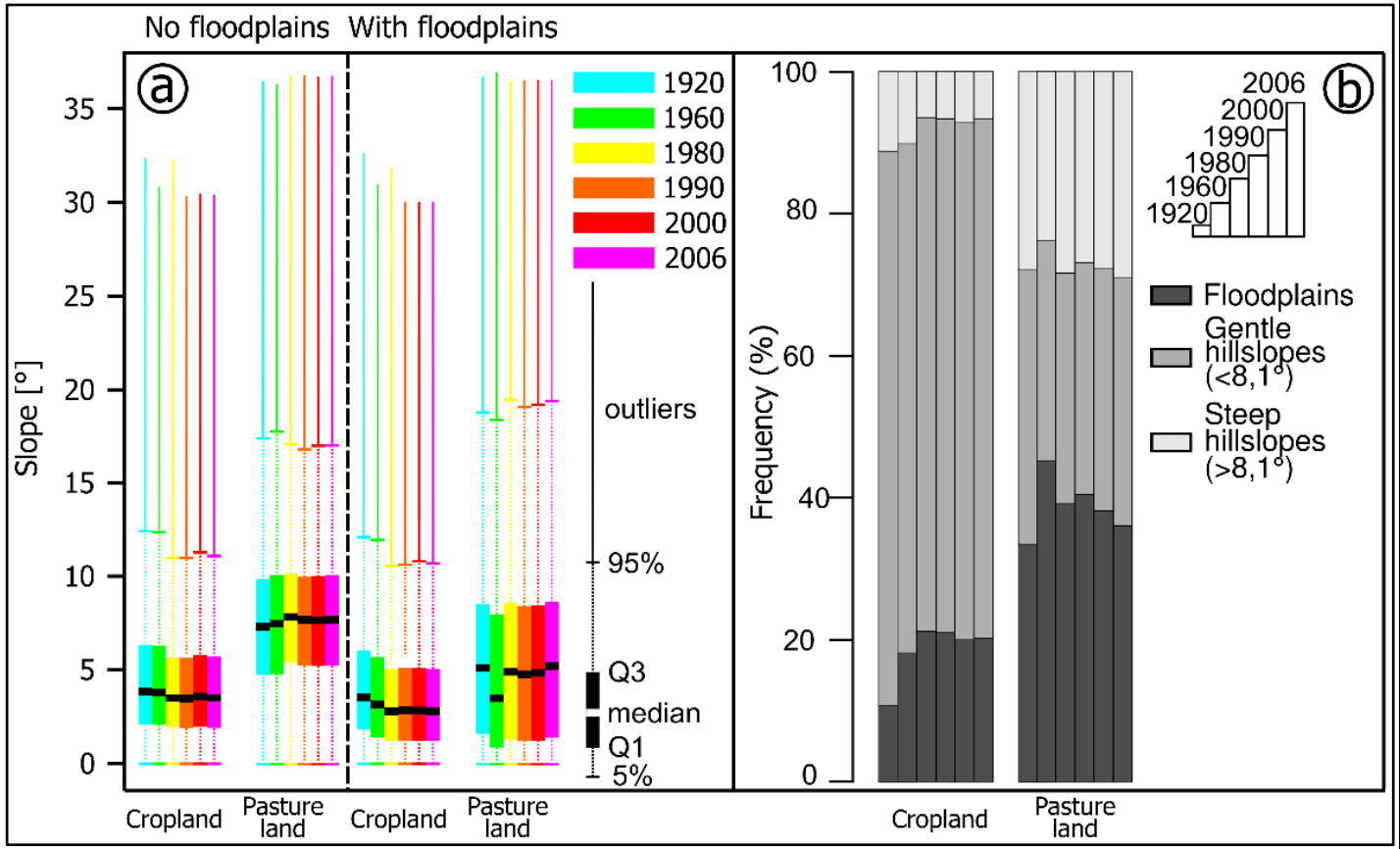
Dynamics of land use **as balance** in Iaşi County for the 1920-2006 period (percent of present-day county surface of 5477.411125 km^2)



The Sankey plot with the temporal fluxes of land use change from pastures to other land-use types (the segment size is proportional to the land use surface for every dataset, while the segment size is proportional to the land use flux from a certain type to the other, but the sizes are not scaled to the absolute values).



The Sankey plot with the temporal fluxes of land use change from other land-use types to pastures (the segment size is proportional to the land use surface for every dataset, while the segment size is proportional to the land use flux from a certain type to the other, but the sizes are not scaled to the absolute values)



The slope and landforms statistics by cropland and pasture land in Iași County (period 1920-2006).

Aerial imagery from 1959 shows the area of Buda village, Brăești commune; the village is located on the floodplain and the adjacent toe slope, the cropland plots extending on the steep hillslope.

Aerial imagery from 1979 shows the area of Buda village, Brăești commune; the cropland plots from the steep hillslope were now joined and converted to pasture; the other cropland plots located on plateaus are joined.

Shading of LiDAR DEM showing the area of Buda village, Brăești commune.

Aerial imagery from 2005 shows Buda village's area, Brăești commune (source ANCPI Geoportal - https://geoportal.ancpi.ro/); the pasture land adjacent to the village is now converted to a forest as a forest erosion control measure, and the cropland parcels are now again fragmented

Aerial imagery from 2018 shows Buda village's area, Brăești commune (source DTM Geoportal - https://portal.geomil.ro/portal/home/); the forest is well established, and the fragmentation of cropland parcels is still present.

As originality from an applied perspective, the **aerial photo-interpretation and the change detection methods** used allowed us the **identification of the spatial distribution of the land use and their dynamics for the XX century in Iași County**. The spatial distribution and the fluxes that were identified allowed us also to associate in a meaningful manner the processes that drove the land use change: urbanization, agricultural conversions, management of flood-prone and of wetlands areas, management of forest areas, respectively other changes that appeared due to various processes.

Agriculture experienced two stages of development: the **extensification of the interwar period** and the **intensification of agriculture during the socialist period**. These phenomena could be quantified with the help of the methodology we used. The extension of **the cropland for the period between 1920 and 1960 on the steep hillslopes, which were previously covered by pastures, is a process that is clearly shown by our data**. This was an organic evolution due to undeveloped agrotechnology, social change, and anthropic pressure. **The wetlands naturally changed to pasture land or cropland during dry years.**

The **communist regime** established after **1945** planned and implemented **measures for soil conservation that reestablished pastures on steep hillslopes**; also, in the context of a drought period in **1950** and the need for flood protection, **floodplain wetlands were converted to pasture lands and croplands**. **After 1990 the changes were not so intense, but there was an extension of pastures lands on unmaintained croplands**.

The knowledge about past land-use changes related to pastures should be the base of future sustainable politics regarding this land-use type. Our results need to be considered when policies target conversions.

Acknowledgments

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SCAN ME

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