Riga-Klaipeda Road Corridor Impacts on the Urbanization and Spatial Structures by Multi-Level Sensors Remote Sensing

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RESEARCH REPORT

INTEREG IV CENTRAL BALTIC

RIGA-KAUNAS-KLAIPEDA ROAD CORRIDORS IMPACTS ON THE URBANIZATION AND THE SPATIAL STRUCTURES BY MULTI-LEVEL SENSORS REMOTE SENSING (2000-2012)

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Remark

This research on the corridors of development is supported by the INTERREG IV Central Baltic Program “Concepts of roadside infrastructure and rest areas”.

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1. Objectives

The objectives of the present research work, made under the INTEREG IV Central Baltic project “Concepts of roadside infrastructure and rest areas“, are:

- The development of a methodology of urban change modeling by remote sensing within the corridors:

  -Riga (Latvia)-Kaunas (Lithuania)

  -Kaunas-Klaipeda

- An analysis of the potential impacts of the corridors on the urbanization and potential environmental impacts.
- The presentation of the created methodology and the results from the built spatial monitoring system.

This research has been supported by the NASA under the Landsat series and DMSP remote sensing image database system in free access for academics and researchers. The image processing and spatial analysis have been made using Envi (geo-referencing), Idrisi (image processing) and ArcGIS (database, image processing result integration and assessment) softwares.

2. Methodology

2. 1. Sequences

The developed methodology can be divided into six sequences:

- The satellite data image acquisition: 1999 to 2012.
- The satellite image and geo-database geo-referencing.
- The urban area recognition and landscape cover visualization by ensemble's operator for each date.
- The urban area and landscape objects (forest, land field, roads, lakes, etc.) by supervised classifier for each date.
- Integration of image processing results in geographic information systems with available databases.
- The spatial analysis of the results; comparison with geographic databases available.

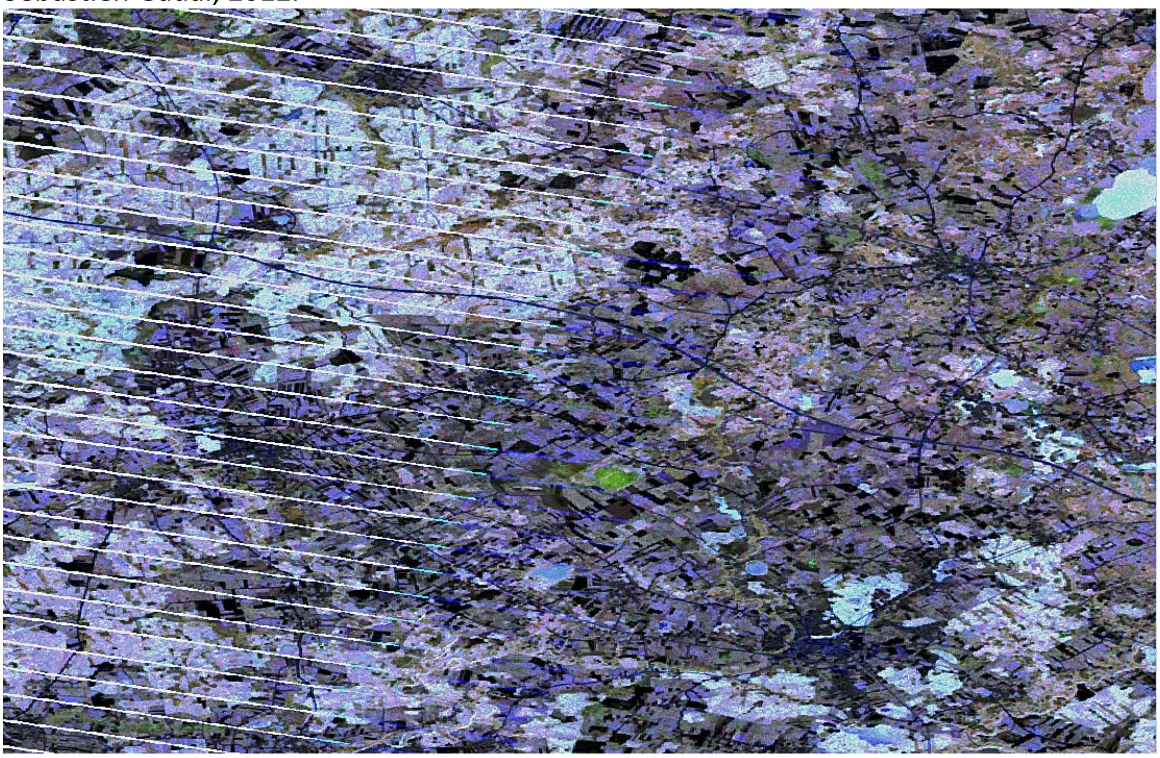
2.2. Methodological schema

The created methodology has mobilized several aspects of the geomatic science:

-the satellite image acquisition: It is done through NASA and USGS data servers. They are freely accessible to researchers and academics. The work consisted of searching regions of interest (ROI), and category available images depending on three criteria: (1) the region of interest covered by the Landsat 5 TM, Landsat 7 ETM +, DMSP F-15 / F-18 OLS-PL, (2) the cloud coverage (below 10%), (3) and the spectral quality images. Satellite images must have all these criteria. The cloud covers draping the areas of interest is one the most important criterion. The season is also important: the images taken in the winter are not usable to recognize roads, habitats, detect forests, fields (snow or spectral response of the low chlorophyll), etc. In addition, the images from the ETM + sensor have significant problems of geometric distortions. The results in the image are the black lines (no spectral measurement) with the exception of the central zone.

Figure 1: Example of geometric distortions on Landsat 7 ETM+ data

Legend: Landsat 7 ETM+, Klaipeda region, 01/05/2012, Recognition of Urban areas and road infrastructures (gold) by ensemble operator, missing information (black stripes) Sébastien Gadal, 2012.



Legend: Idem, color inversion, missing information (white stripes), Sébastien Gadal

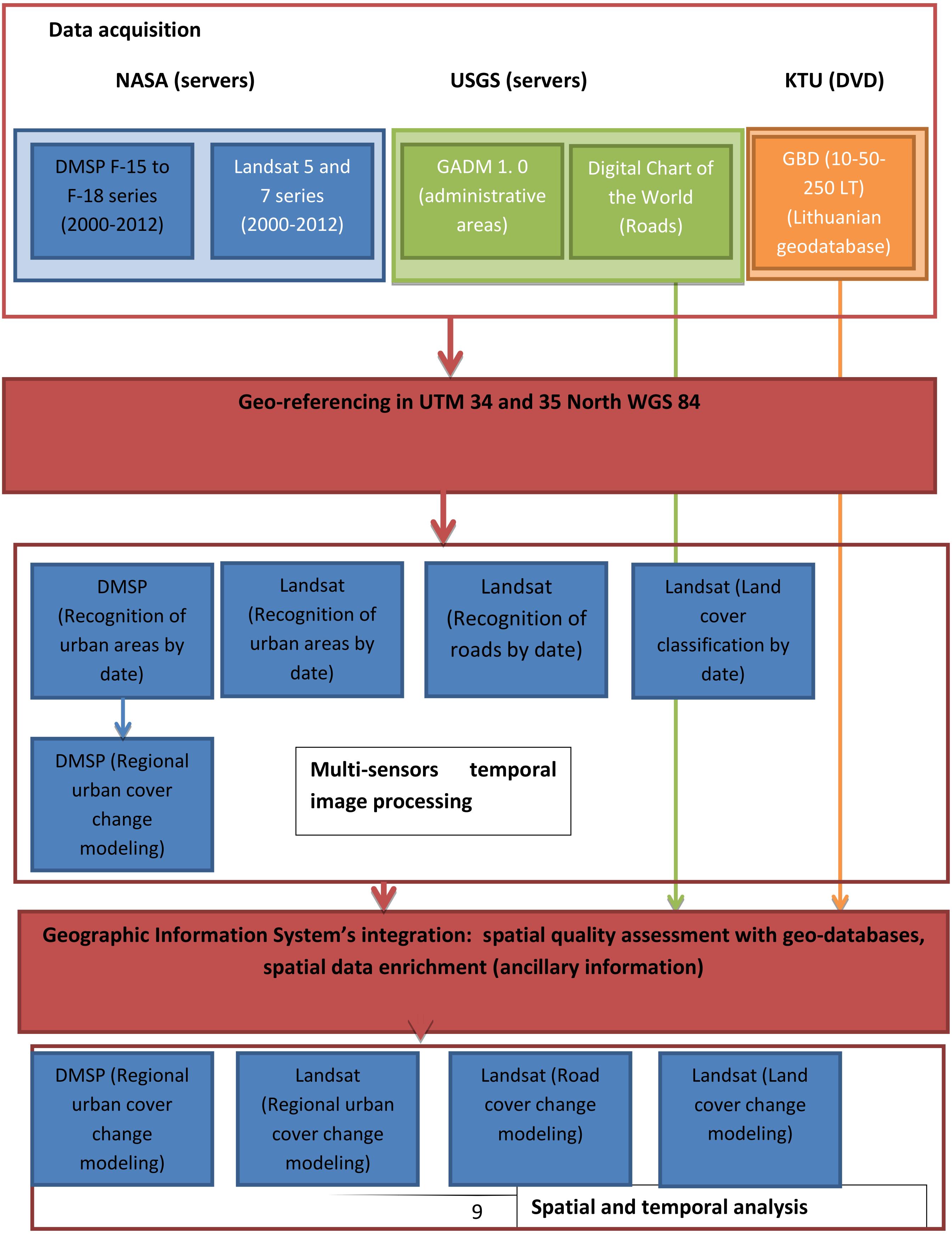
-The data geo-referencing: All the image and geographical databases were geo-referenced in UTM North WGPS 84 (areas 34 and 35). The importance of the geo-referencing of all geographic data is twofold: (1) provide for use, compare, merge, etc. all geographic data, (2) generate temporal modeling of land use change (urbanization, construction or renovation of roads, forests, fields, lakes, rivers, etc.) This requires one geodesic referential to perform the datum and its processing operations on geographic information.

-The image-processing sequence: There are four sequences of processing: (1) the recognition of urban areas at the regional level from DMSP images taken at night with the OLS-PL VNIR sensor (Visible near infrared). (2) The temporal modeling of urban growth between 2000 and 2012 at the regional level by image fusion and statistical redistribution methodologies. (3) The recognition of urban areas and roads by spectral responses of geographic objects' fusion operator using Landsat 5 TM and Landsat 7 ETM+. (4) The image taxonomy of the land covers by unsupervised and supervised automatic classifications from Landsat 5 TM and Landsat 7 ETM+ satellite data.

-The geo-database and image-processing results integration in Geographic information system (GIS): The integration of all the results of image processing, the geographic databases (GBD 10, 50 and 250 LT, DCW, GADM, LV GIS) and the raw satellite images, has the advantage of evaluating the quality of modeling and detecting the errors. They are quite numerous in the geographic databases. But, also, it has for interest to complete the image analysis by providing ancillaries geographic information.

-The spatial and temporal analysis: The spatial analysis concerns the study, combining the urban growth, the evolution of land cover, and the potential impact of the *Via Baltica* and Kaunas-Klaipeda highway on the geographic structures and the spatial dynamics. It follows also the segments of the *Via Baltica* under construction by remote sensing in 1999.

Figure 2: General schema of sequential operation of geographic data

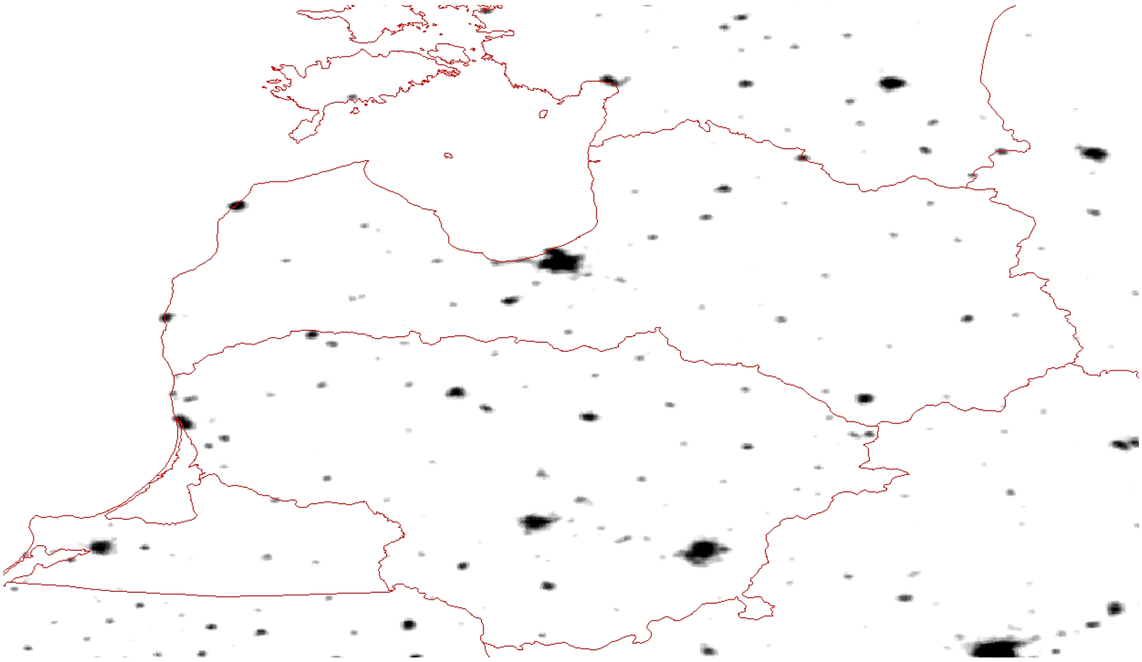


2.3. Image remote sensing acquisition

2. 3. 1. DMSP series

The interest of the DMSP data is to cover all the region of interest (Lithuanian and Latvian territories) at the regional level; but also, by the level of data acquisition regularities, to analyze and modeling the urban change and the urban growth during the last 12 years. The spatial resolution of 1km² permits to recognize major urban areas of the Baltic region. The detection of the urban areas is made by the spectral measure in the visible near infrared sensor by night.

Figure 3: Example of DMSP OLS image from 2000

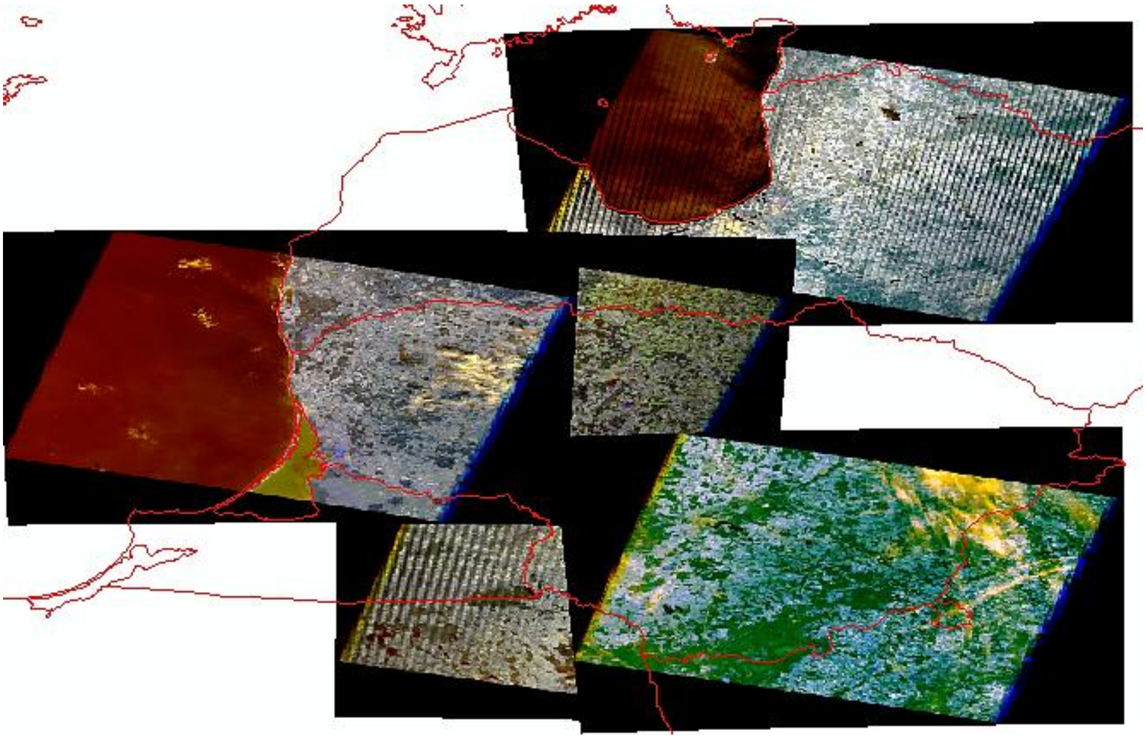


Legend: Detection of major urban areas by DMSP F-15 OLS (in black and grey), Borders of the countries (red), DCW, Sébastien Gadal, 2012.

2. 3. 2. Landsat series

The Landsat 5 Thematic Mapper (TM) and Landsat 7 (Enhancement Thematic Mapper) ETM+ are the only medium resolution satellite data in free access for the researchers and the academics on the NASA database servers. They are covering region of interest of 175x185 km with a spatial resolution of 30x30 meters in 6 spectral intervals (spectral bands) on the visible (VIS), near infrared (NIR), and middle infrared (MIR) (plus a spectral thermal infrared interval, the spectral band 7). The interest of the Landsat series is the large temporal available data from the middle of the 1970’s. The spatial resolution of 900m² allows the detection and the recognition of urban areas, villages and hamlets.

Figure 4: Example of Landsat mosaic on the region of interest (Riga-Kaunas-Klaipeda) in 2012



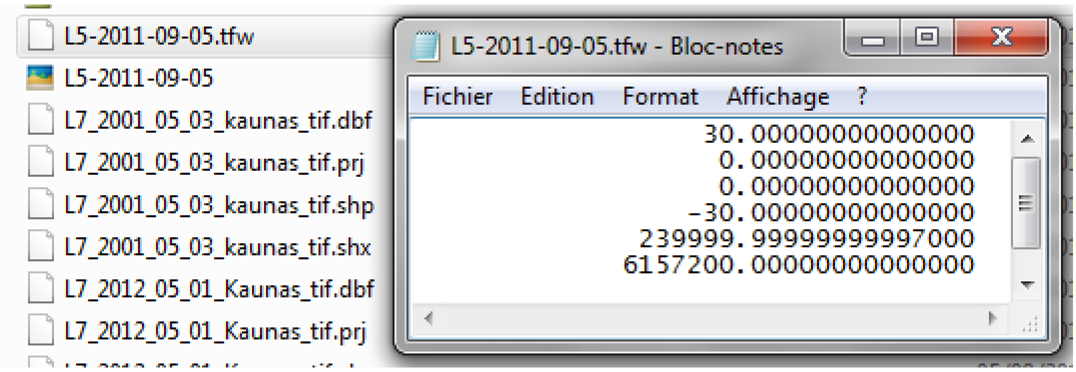
Legend: color composition mosaic made by Landsat 5 TM / Landsat 7 ETM+, Sébastien Gadal, 2012.

2.4 Geo-referencing satellite data in Universal Transverse of Mercator (UTM)

The choice of the UTM geodesic coordinate system of projection is because of the use of the satellite images. All the satellite images integrate the Universal Transverse of Mercator geodesic coordinate system. It covers all the surface of the Earth. UTM geodesic coordinate system is linked to the GPS WGS 84, as the Lithuanian geo-database, the GADM and the DCW geo-databases.

The .tif raster format of the satellite images is geo-referenced. The geodesic coordinates are included in the file .tfw.

Figure 5: Example of the .tfw coordinate contents (UTM geodesic coordinate system)

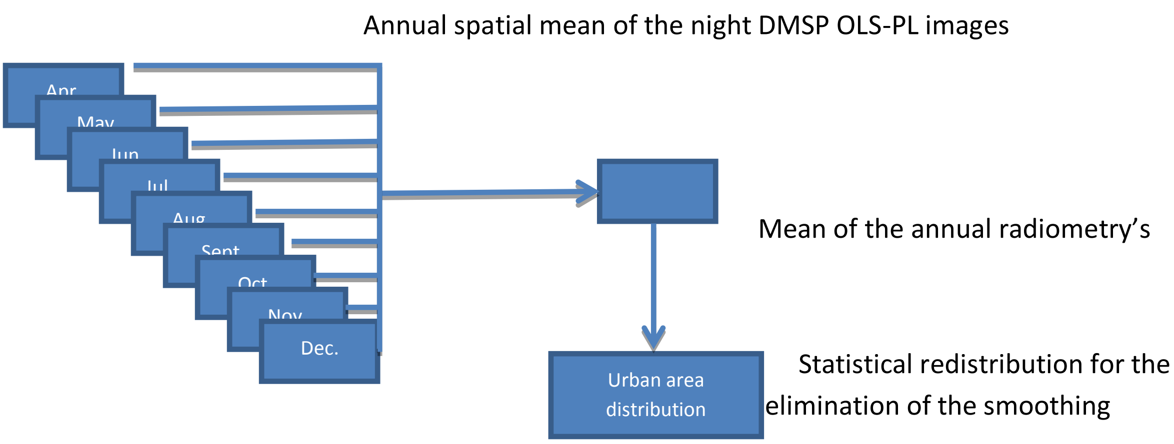


Legend: visualization from the built geo-database, Sébastien Gadal, 2012.

2.5. Recognition of urban areas by DMSP OLS-PL remote sensing sensor

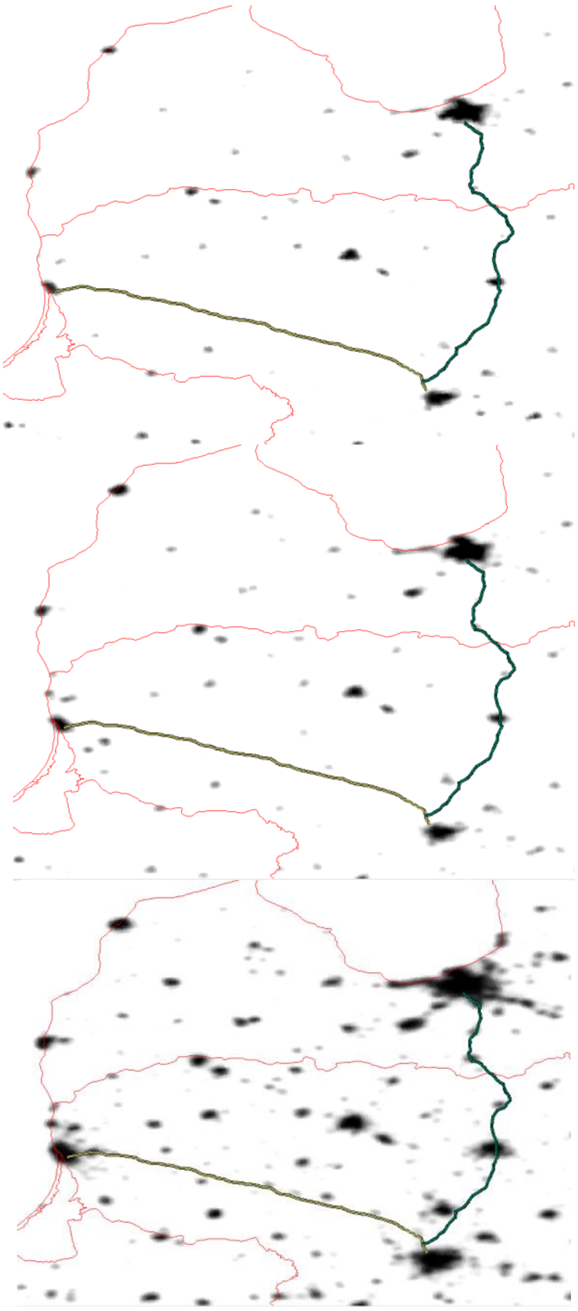
2.5.1. Methodology of urban area recognition

Figure 6: Sequences of image-processing



2.5.2. Identification of urban areas at the regional level

Figure 7: Urban areas recognized in 1992, 2000, and 2010



Urban areas recognized within the Via Baltica and the Kaunas-Klaipeda highway in 1992

Urban areas recognized within the Via Baltica and the Kaunas-Klaipeda highway in 2000

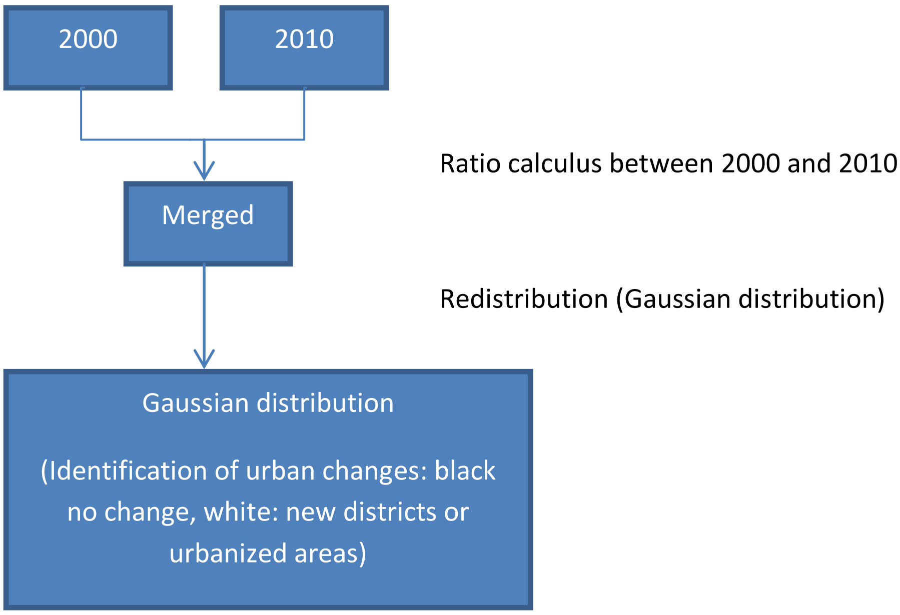
Urban areas recognized within the Via Baltica and the Kaunas-Klaipeda highway in 2010

Legend: Urban growth from 1992 to 2010 (black and grey levels), Via Baltica (dark green), Kaunas-Klaipeda highway (green olive), borders of the countries (red), Sébastien Gadal, 2012

2.6. Temporal Modeling of the urban growth with DMSP OLS remote sensing sensor

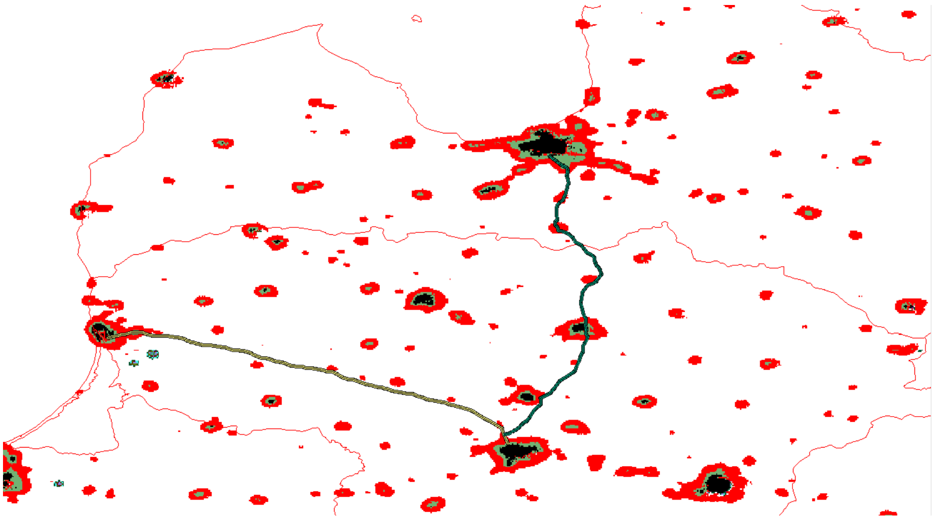
2.6.1. Methodologies of urban change modeling: ratio method

Figure 8: Methodology based on ratio calculus (between two dates)



2.6.2. Urban change modeling (2000-2010) (Figure 9)

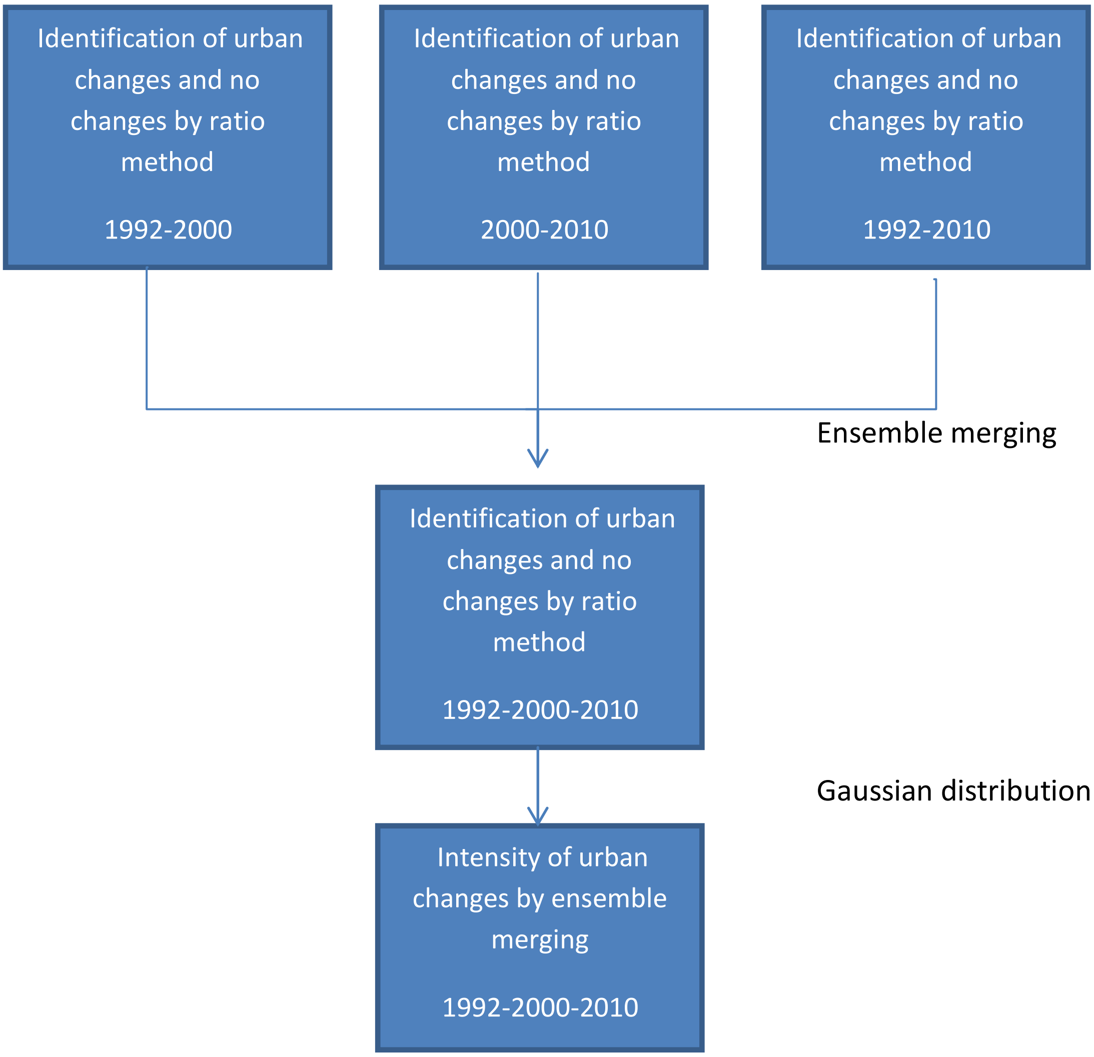
Recognition of the urban change between 2000 and 2010



Legend: no change (black), zone under construction in 2000 (green), urban growth from 2000 to 2010 (red), Via Baltica (dark green), Kaunas-Klaipeda highway (green olive), borders of the countries (red), Sébastien Gadal, 2012.

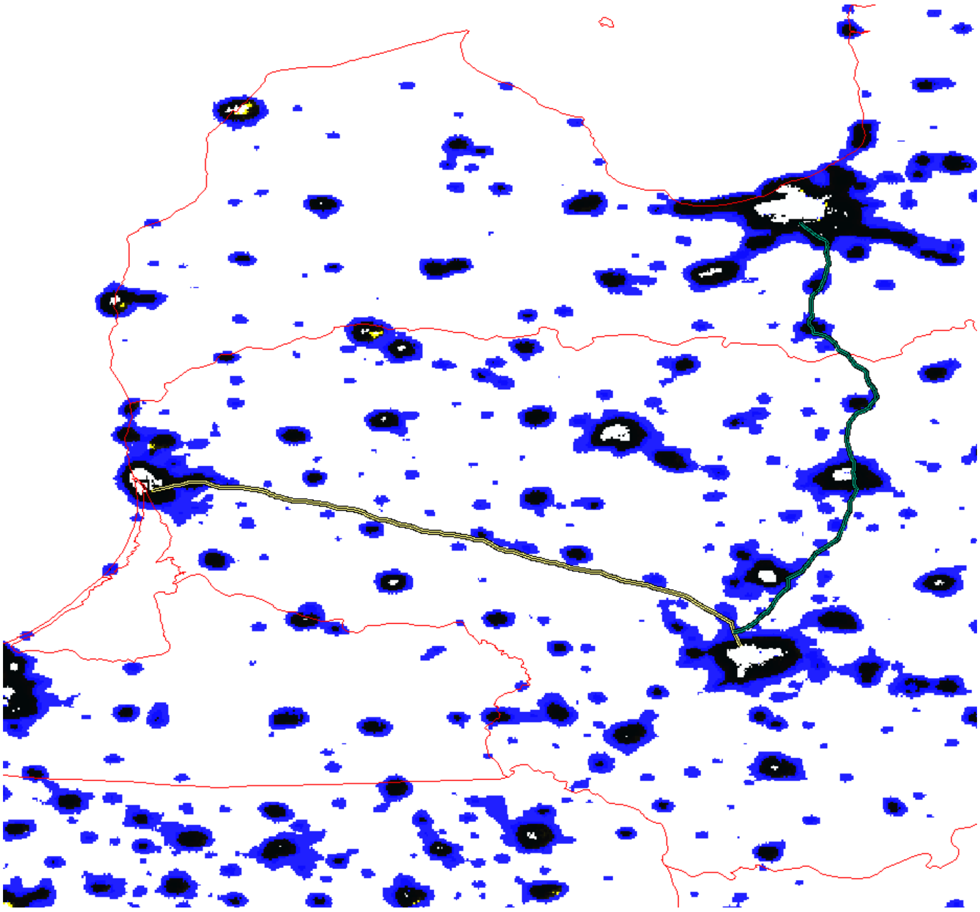
2.6.3. Methodologies of urban change modeling: Intensity modeling

Figure 10: Methodology of urban intensity change modeling



2.6.4. Intensity of the urban change (1992-2000-2010) (Figure 11)

Intensity of the urban change between 2000 and 2010



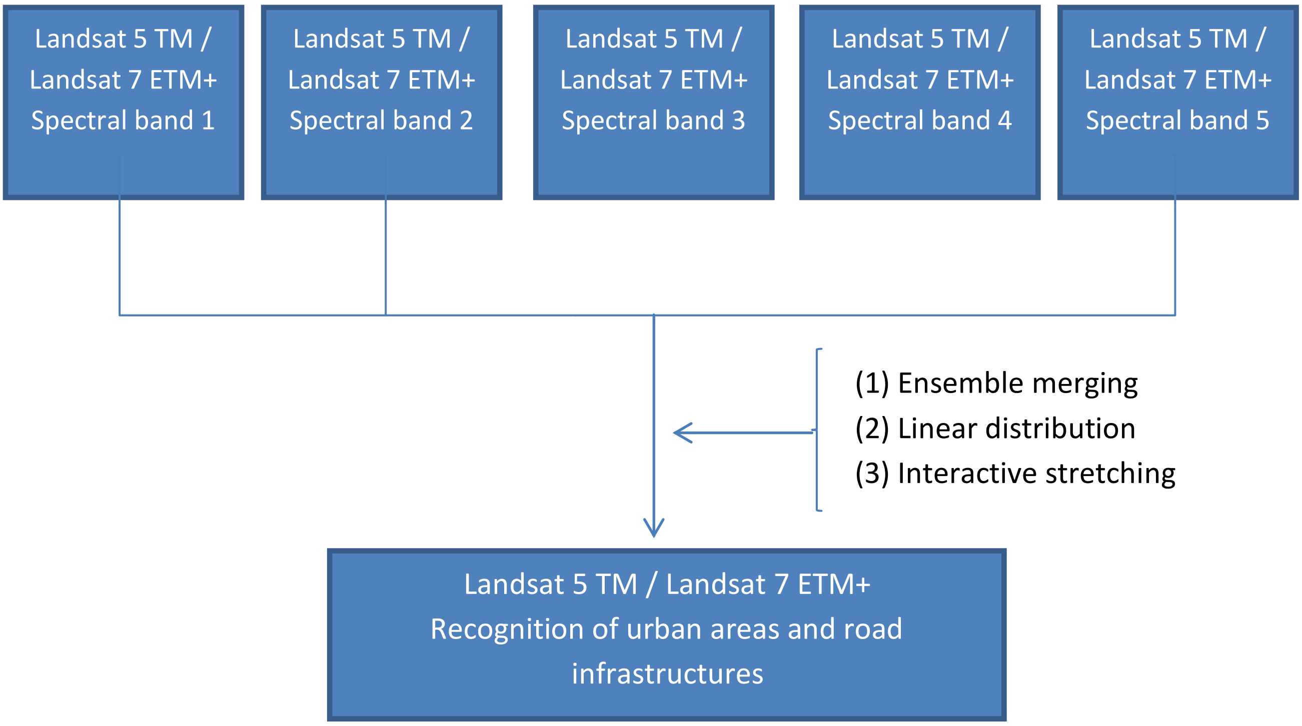
Legend: White Blue Black

Low Intensity High Intensity

Sébastien Gadal, 2012

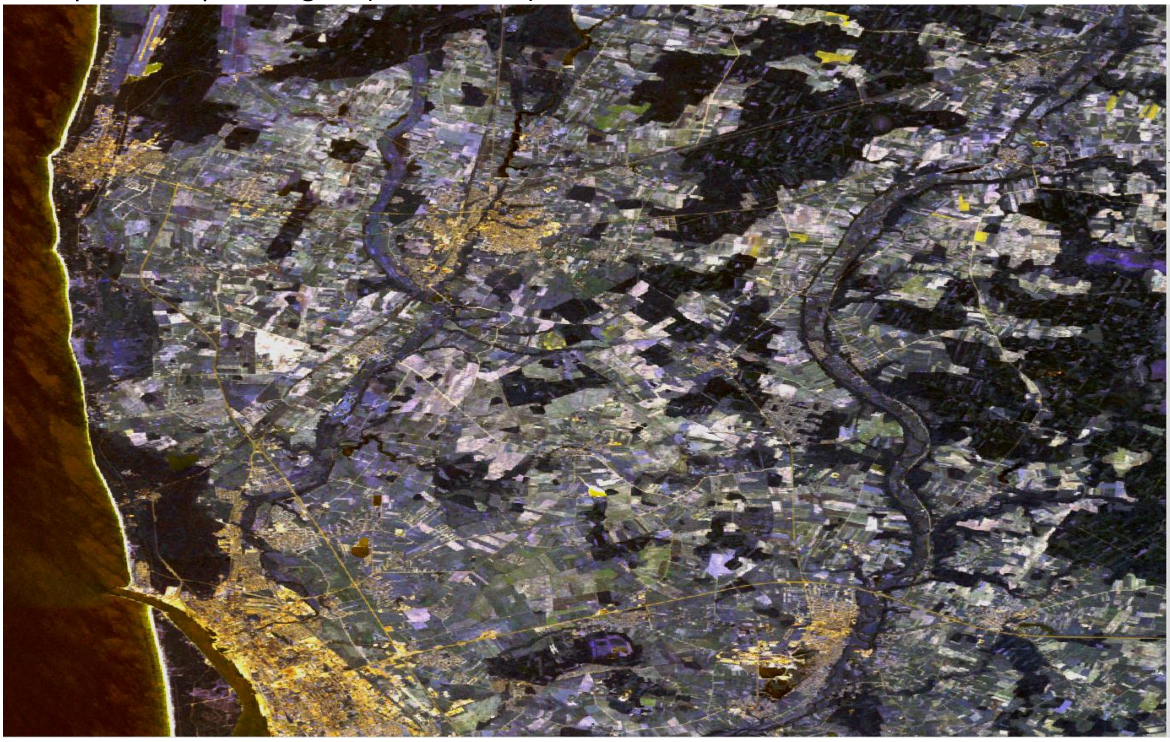
2.7. Recognition of urban areas and road infrastructures by Landsat 5 TM and Landsat 7 ETM+ remote sensing sensors

2.7.1. Sequences of image-processing (Figure 12)



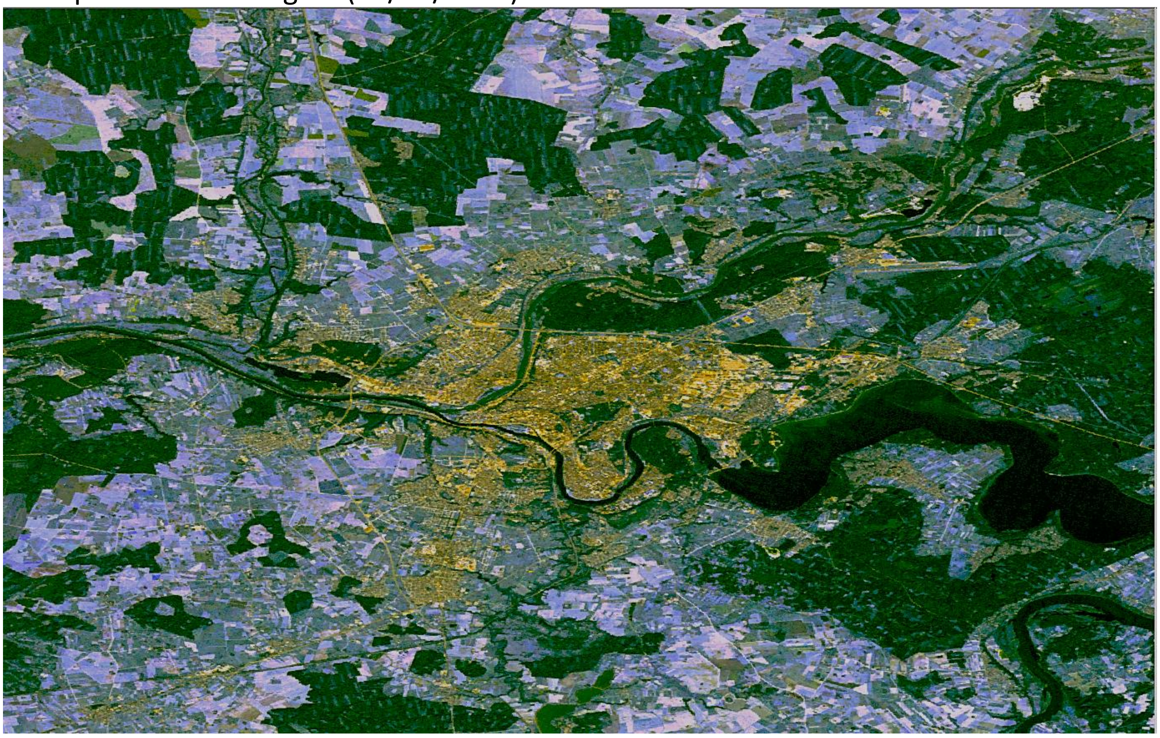
2.7.2. Examples of urban areas recognized (Figure 13)

Example of Klaipeda region (06/06/2011)



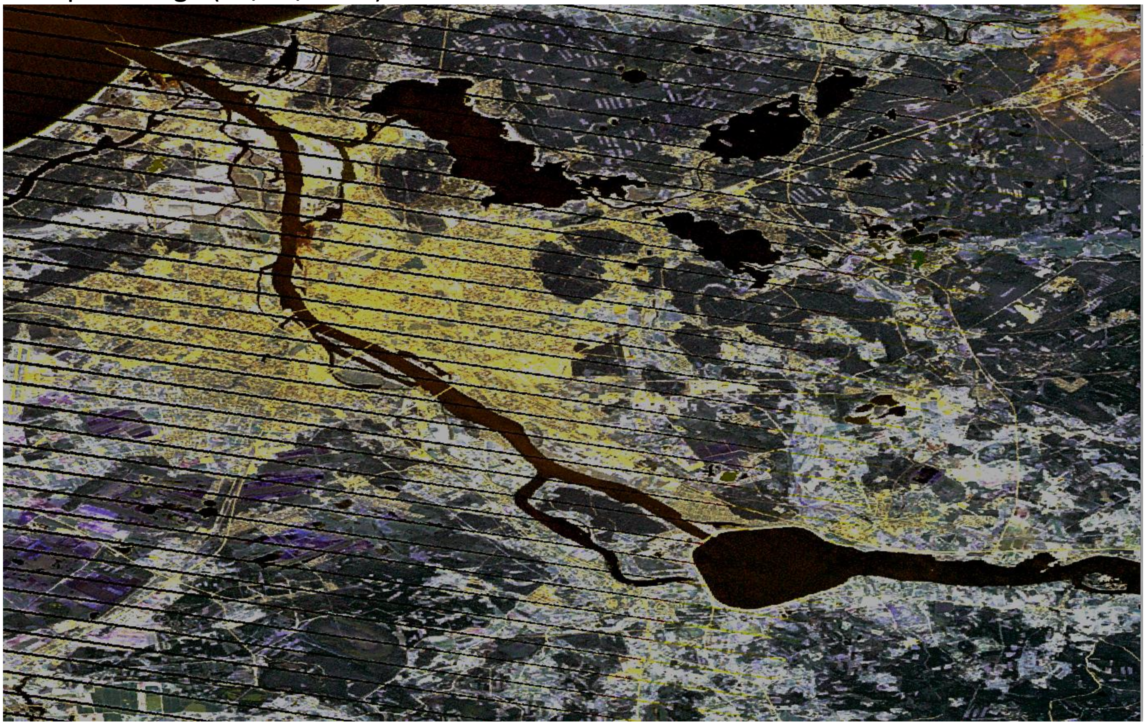
Legend: urban areas and road infrastructures (gold), Landsat 5 TM, Sébastien Gadal, 2012

Example of Kaunas region (05/09/2011)



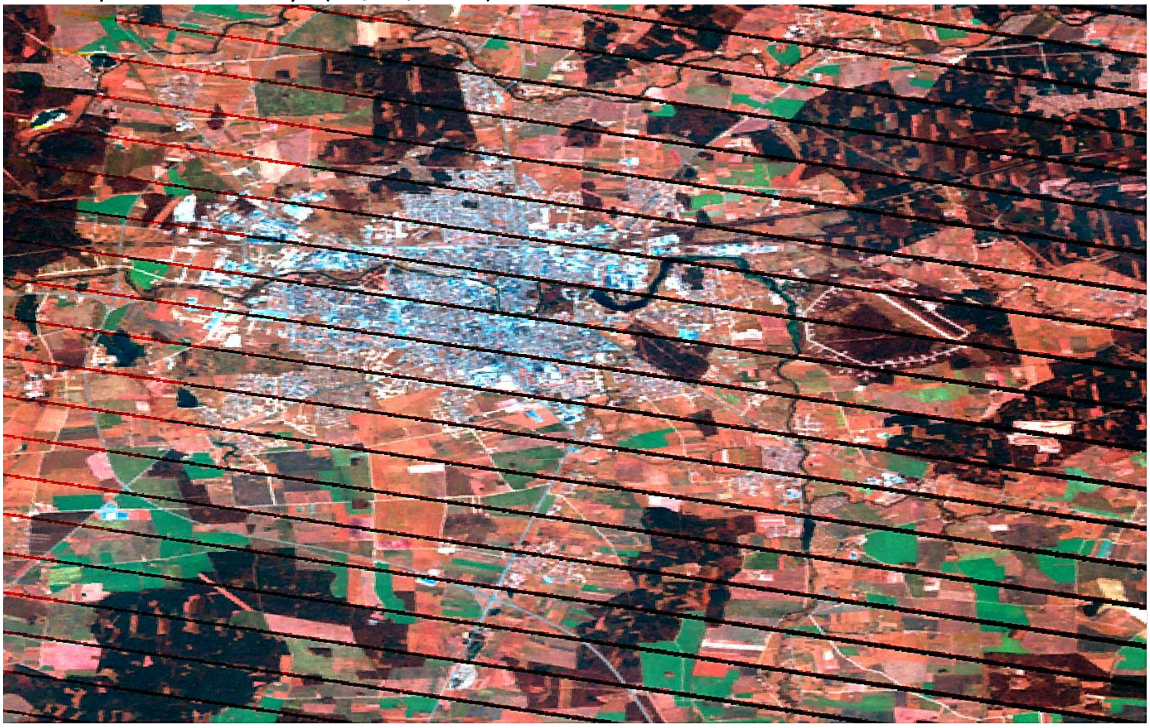
Legend: urban areas and road infrastructures (gold), Landsat 5 TM, Sébastien Gadal, 2012

Example of Riga (01/05/2012)



Legend: urban areas and road infrastructures (gold), Landsat 7 ETM+, Sébastien Gadal, 2012

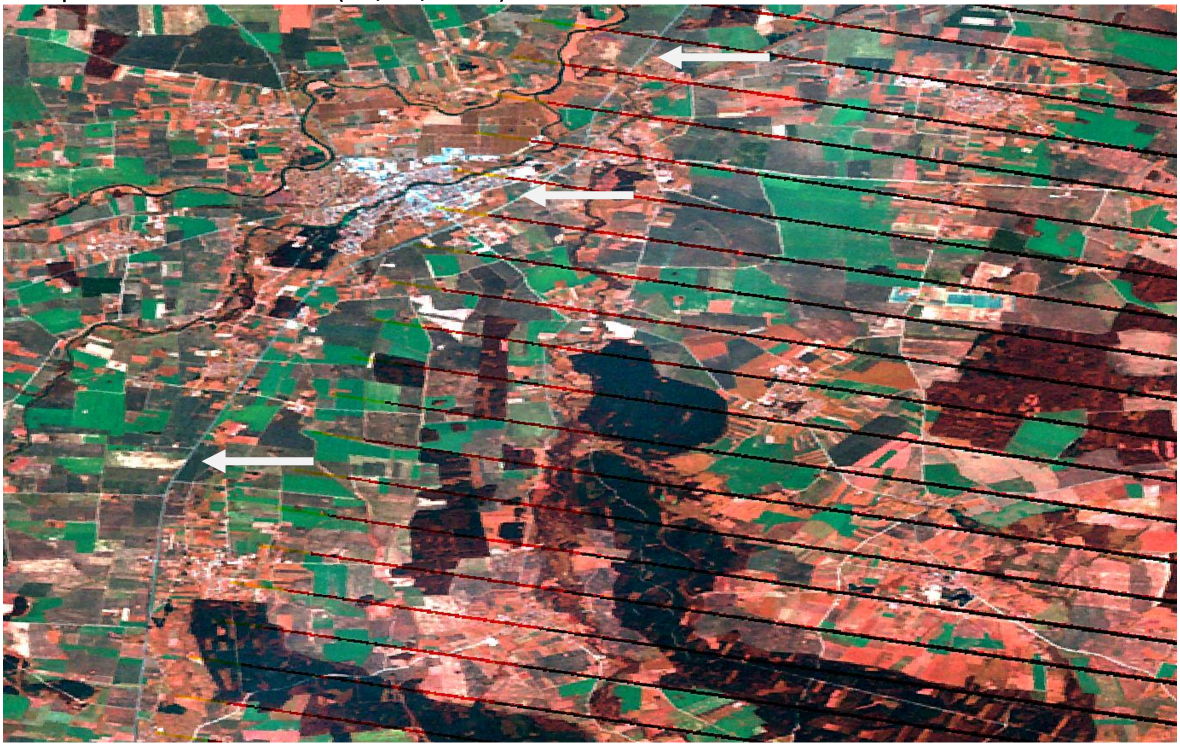
Example of Panevezys (01/07/2011)



Legend: urban areas and road infrastructures (blue), Landsat 7 ETM+, Sébastien Gadal, 2012

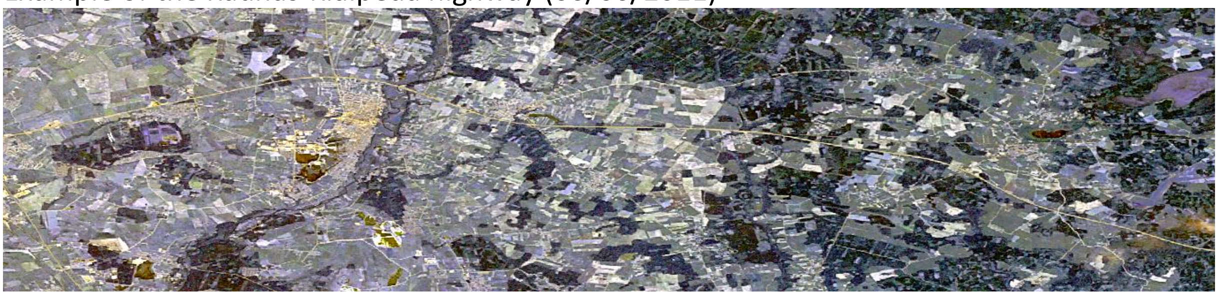
2.7.3. Examples of road infrastructures recognized (Figure 14)

Example of the Via Baltica (01/07/2011)



Legend: urban areas and road infrastructures (blue), Landsat 7 ETM+, Sébastien Gadal, 2012

Example of the Kaunas-Klaipeda highway (06/06/2011)

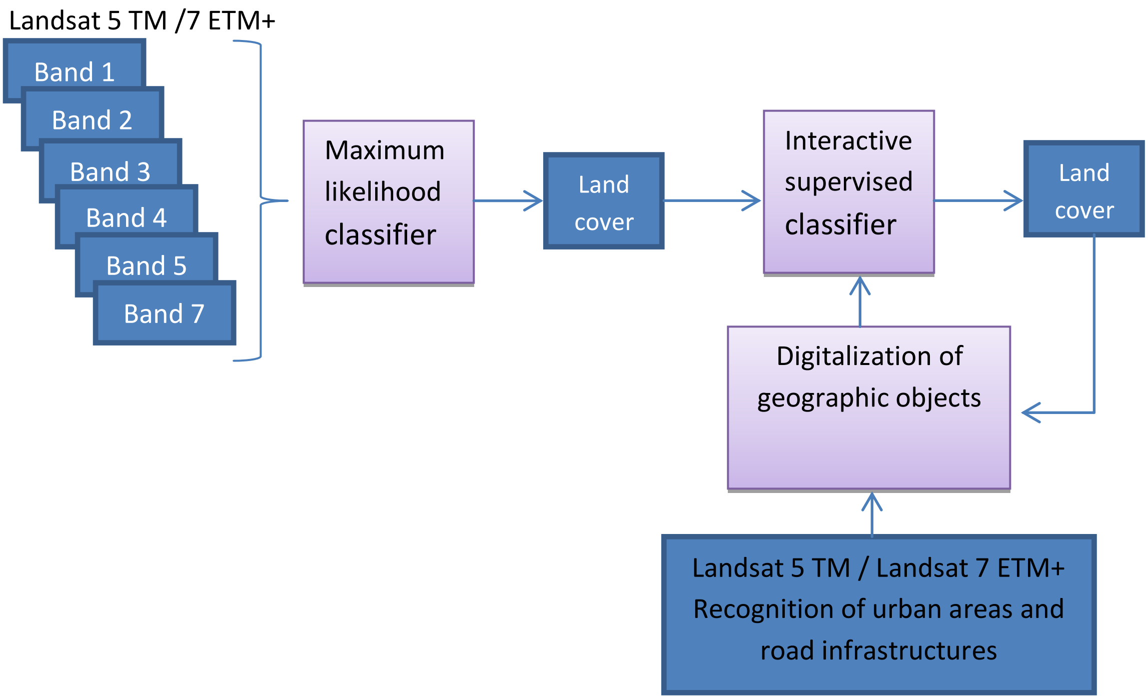


Legend: urban areas and road infrastructures (blue), Landsat 5 TM, Sébastien Gadal, 2012

3. Image analysis and interpretation

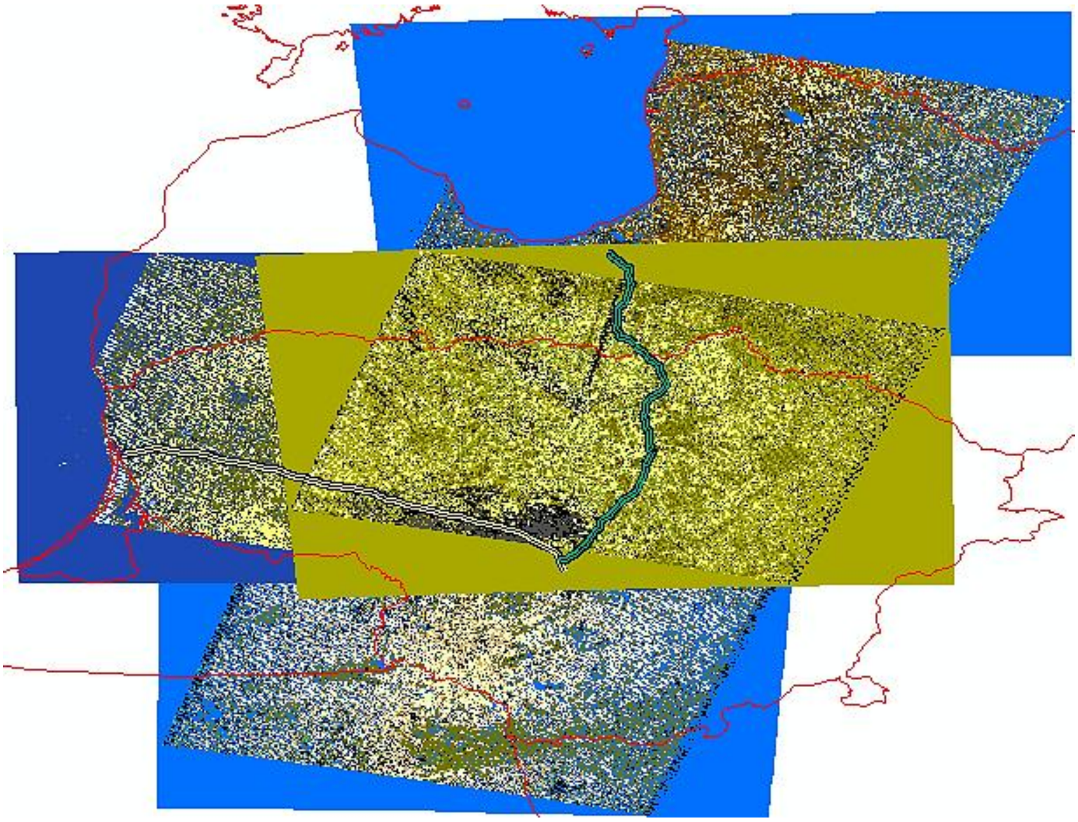
3.1. Urban land cover change

3.1.1. Methodology (Figure 15)



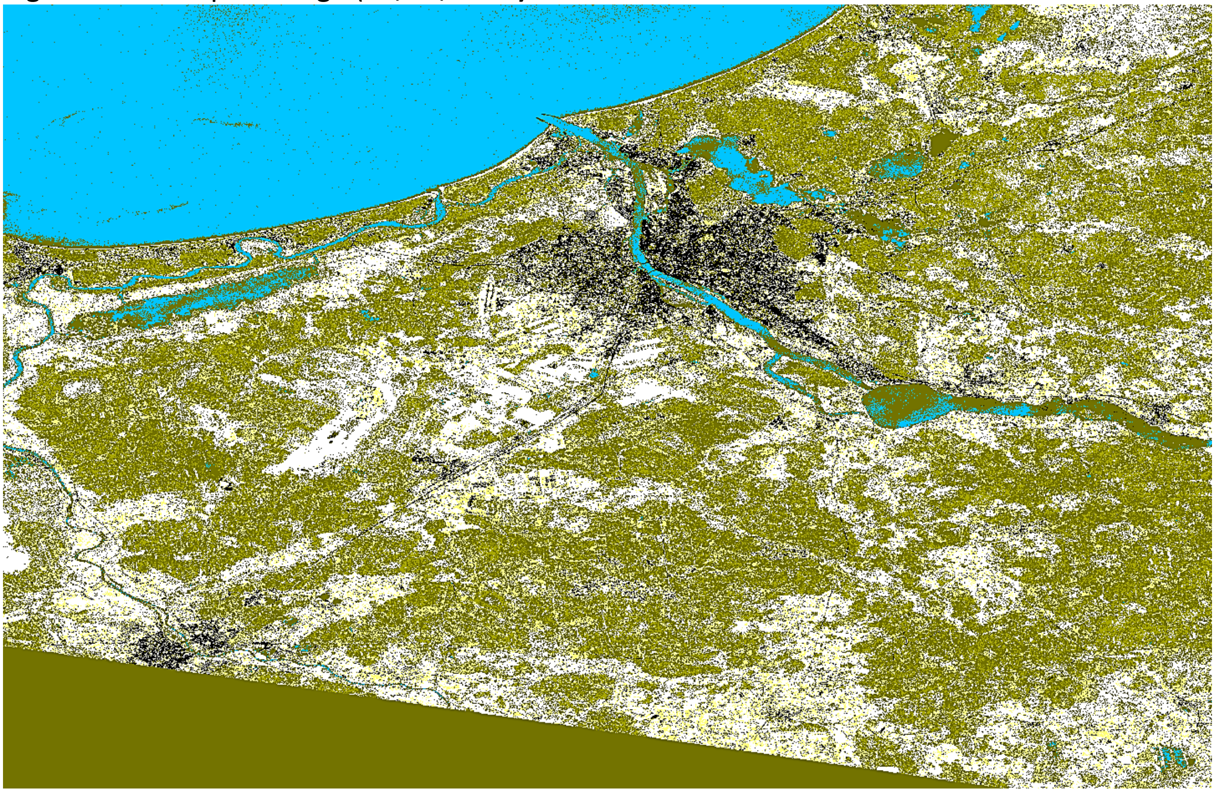
3. 1. 2. Examples of land covers (Figures 16, 17, 18, 19 and 20)

Figure 16: Example of the region of interest (Via Baltica and Kaunas-Klaipeda highway) (2012)



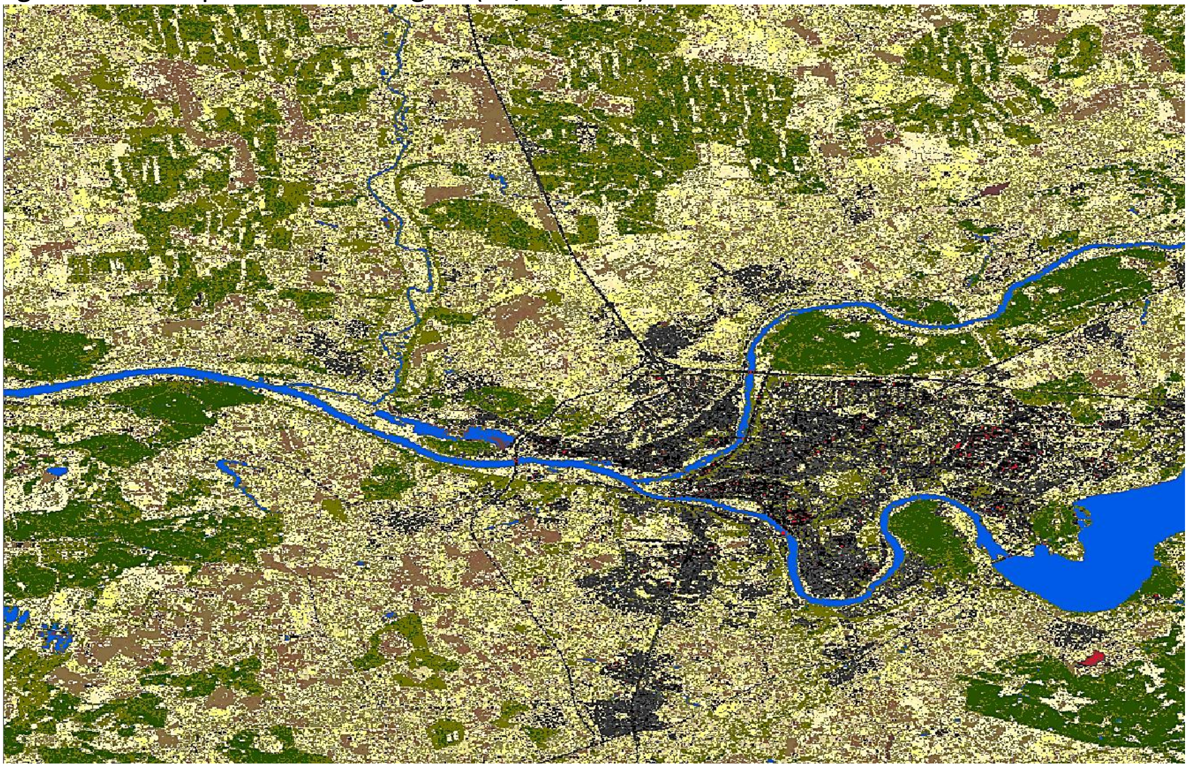
Legend: Land cover classification, Landsat 7 ETM+, Sébastien Gadal, 2012

Figure 17: Example of Riga (02/08/1999**)**



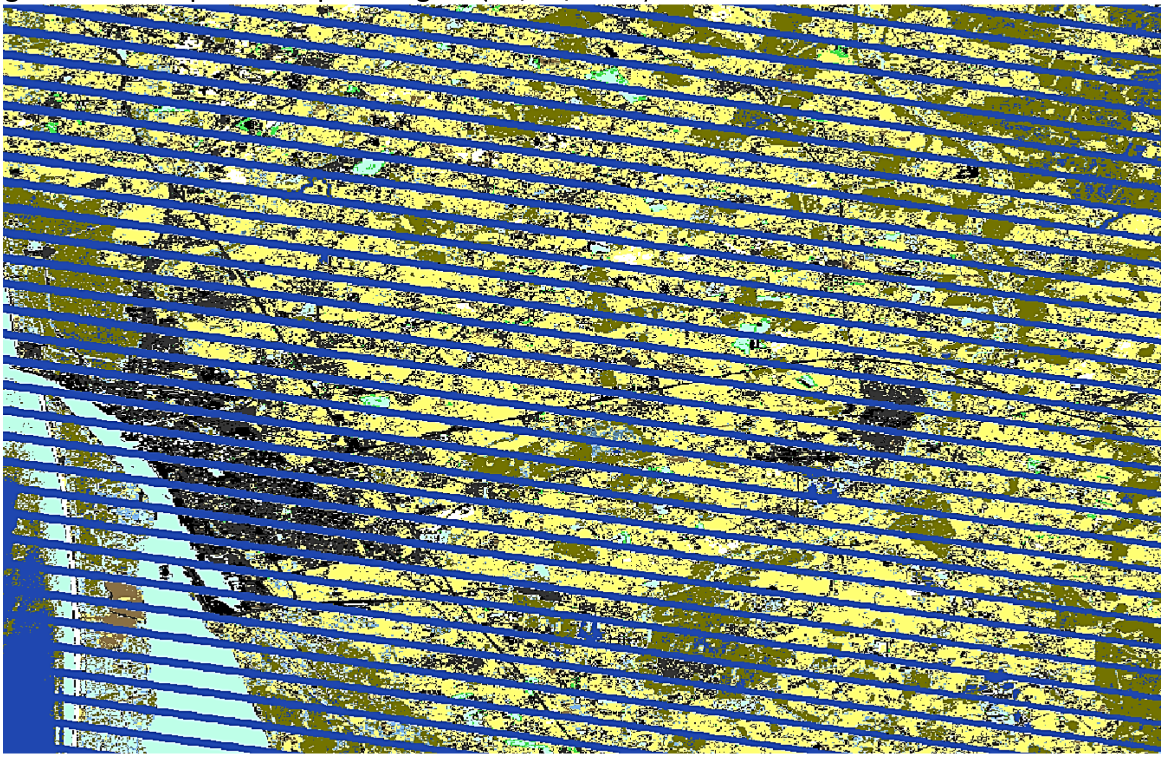
Legend: Land cover classification, Landsat 7 ETM+, Sébastien Gadal, 2012

Figure 18: Example of Kaunas region (03/05/2001)



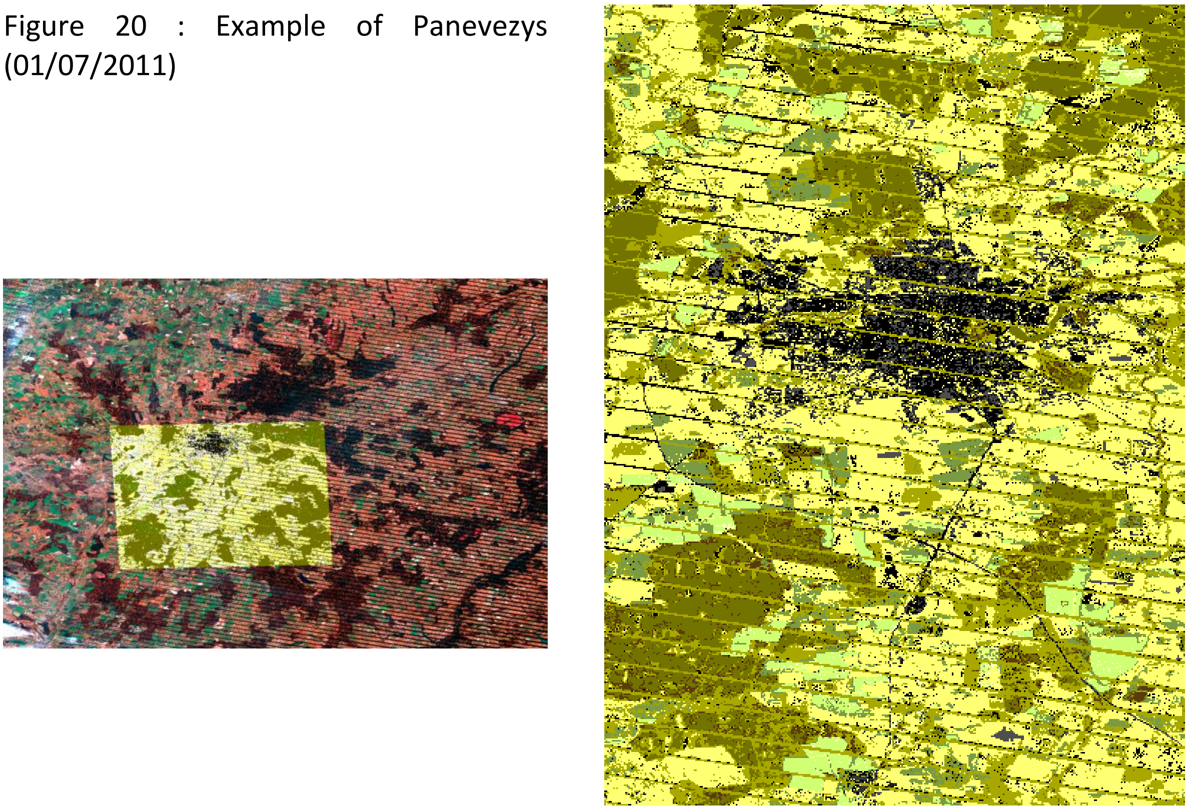
Legend: Land cover classification, Landsat 7 ETM+, Sébastien Gadal, 2012

Figure 19: Example of Klaipeda region (24/05/2012)



Legend: Land cover classification, Landsat 7 ETM+, Sébastien Gadal, 2012

Figure 20 : Example of Panevezys (01/07/2011)



Legend: Land cover classification, Landsat 7 ETM+, Sébastien Gadal, 2012

3.2. Multi-dates modeling of the urban changes

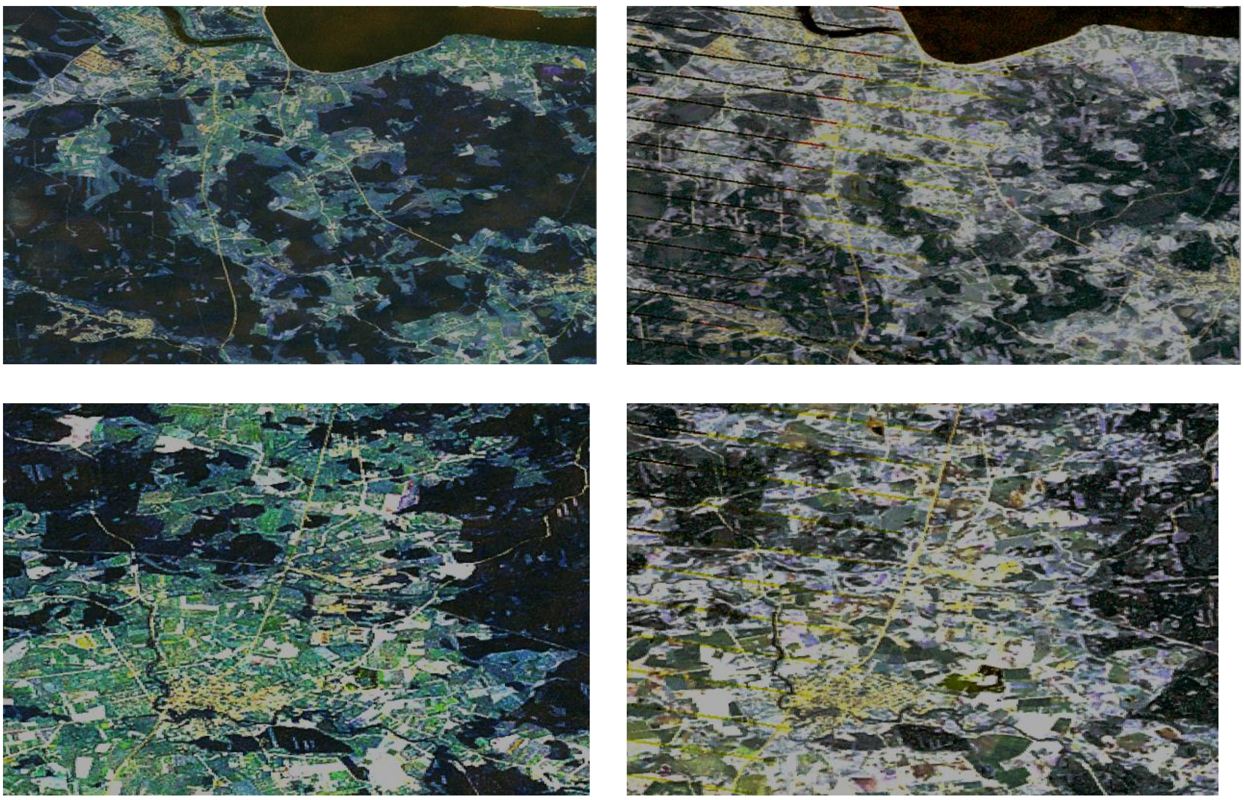
3.2.1. Examples of urban changes impacts recognition by remote sensing image processing

The *Via Baltica* has a low influence on the processes of sub-urbanization. The road impact on the suburban growth of Riga is limited between 1999 and 2012. The classifications made in 1999 and 2012 measure a phenomenon of urban densification. In any case, a limited dynamic of urban extension of the villages located within or near the *Via Baltica* road characterizes the process of Riga's urbanization. The area of existing villages increases. It is more associated to the densification and the renovation of the buildings and houses.

The monitoring of the urbanization by remote sensing on the *Via Baltica* measures similar territorial process in the town as Bauska located at more than 50 kilometers from Riga city or villages like Lecava (around 25 km from Riga).

Figure 21: Riga's suburban places within the Via Baltica

1999 2012



Legend: Landsat 5 TM, Landsat 7 ETM+, Sébastien Gadal, 2012

Figure 22: Urbanization of Panevezys Region within the Via Baltica

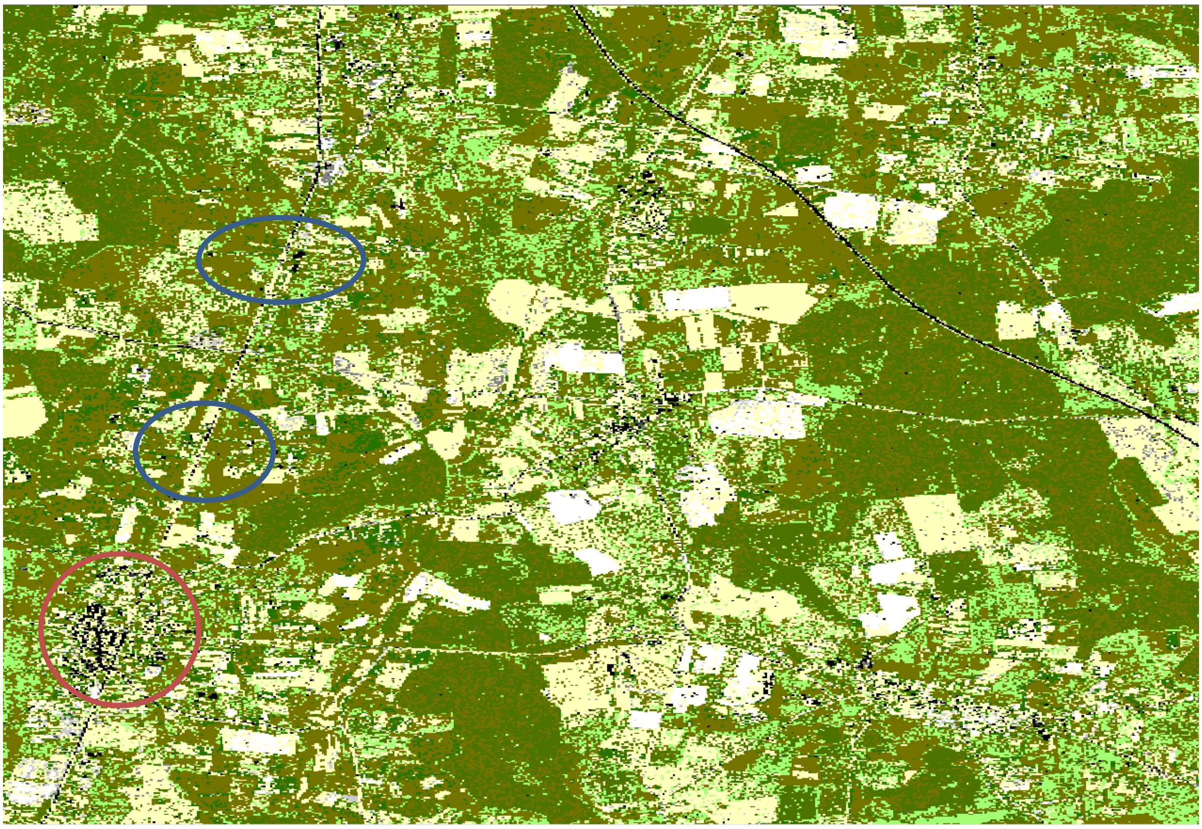
2000

2011

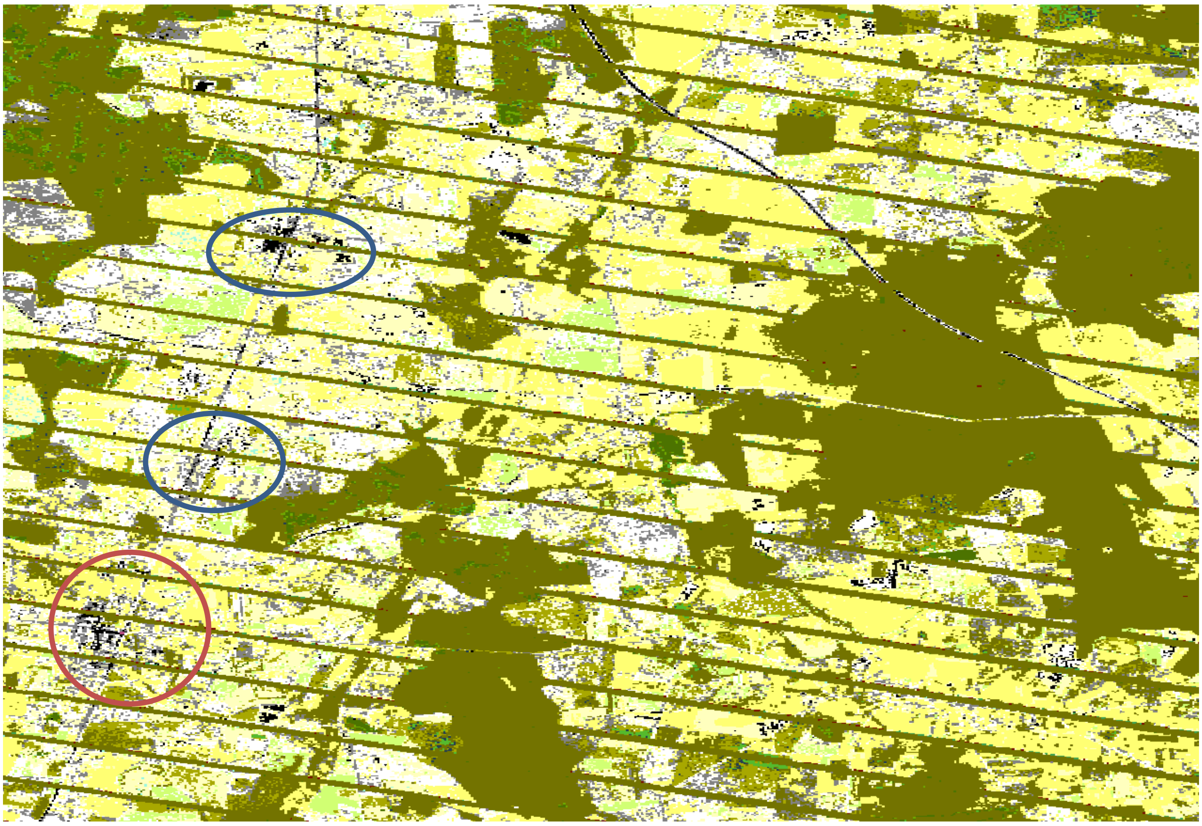
Sébastien Gadal, 2012

Figure 23: Urbanization of Panevezys Region within the Via Baltica (land cover classification)

2000



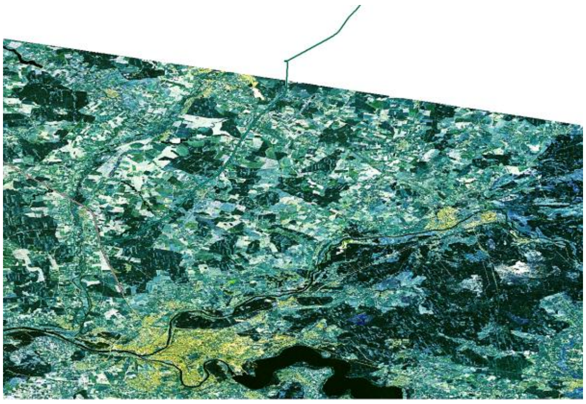
2011



The low quality of the Landsat 7 ETM+ spectral response limits the recognition of villages detected on the year 2000. We observe within the Via Baltica road two categories of urban impact: (1) built areas and house dispersion (blue circles), (2) stable urban areas (red circle), Sébastien Gadal, 2012.

Figure 24: Urbanization of Kaunas region near the Via Baltica

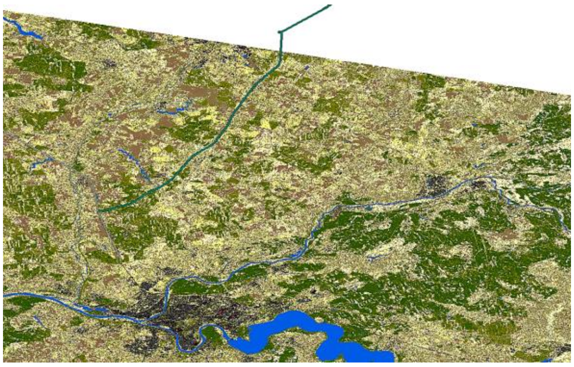
2001



Land cover classification 2001

2011

Land cover classification 2011



Sébastien Gadal, 2012

All the highways crossing Kaunas city are the driving vectors of the suburbanization process (as in the Klaipeda region or in Vilnius urban area). Roads and highways, as the *Via Baltica* and the Kaunas-Klaipeda, freeway structure and organize the metropolitan territory of Kaunas urban area in two major directions: the dynamic of mobility (daily car commuting) and the emergence of the post-soviet suburbanization. The development of the suburban areas is based on the existing villages and allotments. The *Via Baltica* and the Kaunas-Klaipeda highway improve the territorial dynamic of suburbanization, mobility and car commuting around the areas of influences of the towns.

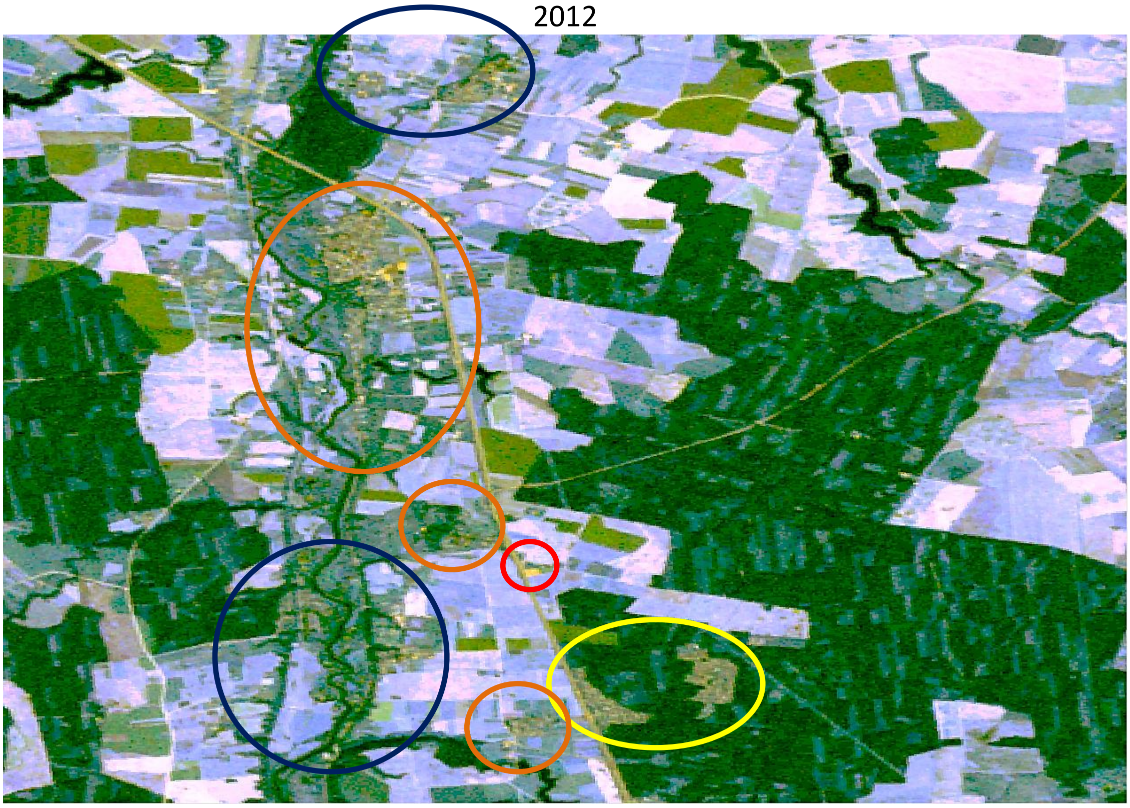
The spatial impact of the suburbanization is more or less limited on the territory within the Kaunas-Klaipeda highway after 15 kilometers from the last suburbs. The urban and the territorial structures are stable. They don’t change. The models of remote sensing recognition measure a growth of the villages, a transformation of the use of the allotments, and an urban densification with the building of new edifices (houses, buildings, industries). But the territorial structures from the soviet period didn’t change after 21 years of the end of the Soviet Union. If the dynamics of suburbanization developments are underway and spatially fit, they are nevertheless limited by the demographic factor.

Figure 25: Suburban villages within the Kaunas-Klaipeda highway and the Via Baltica

2001

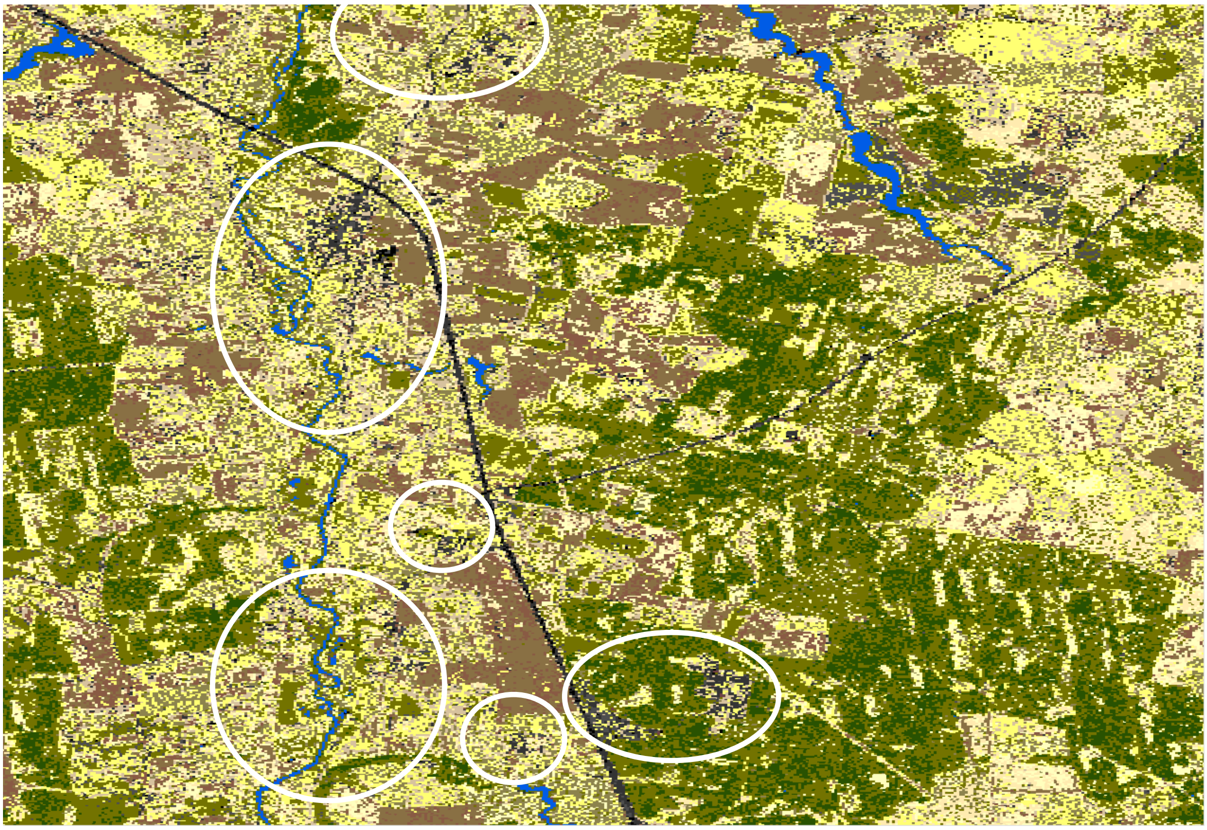
Test zones of changes (white), Sébastien Gadal, 2012

2012



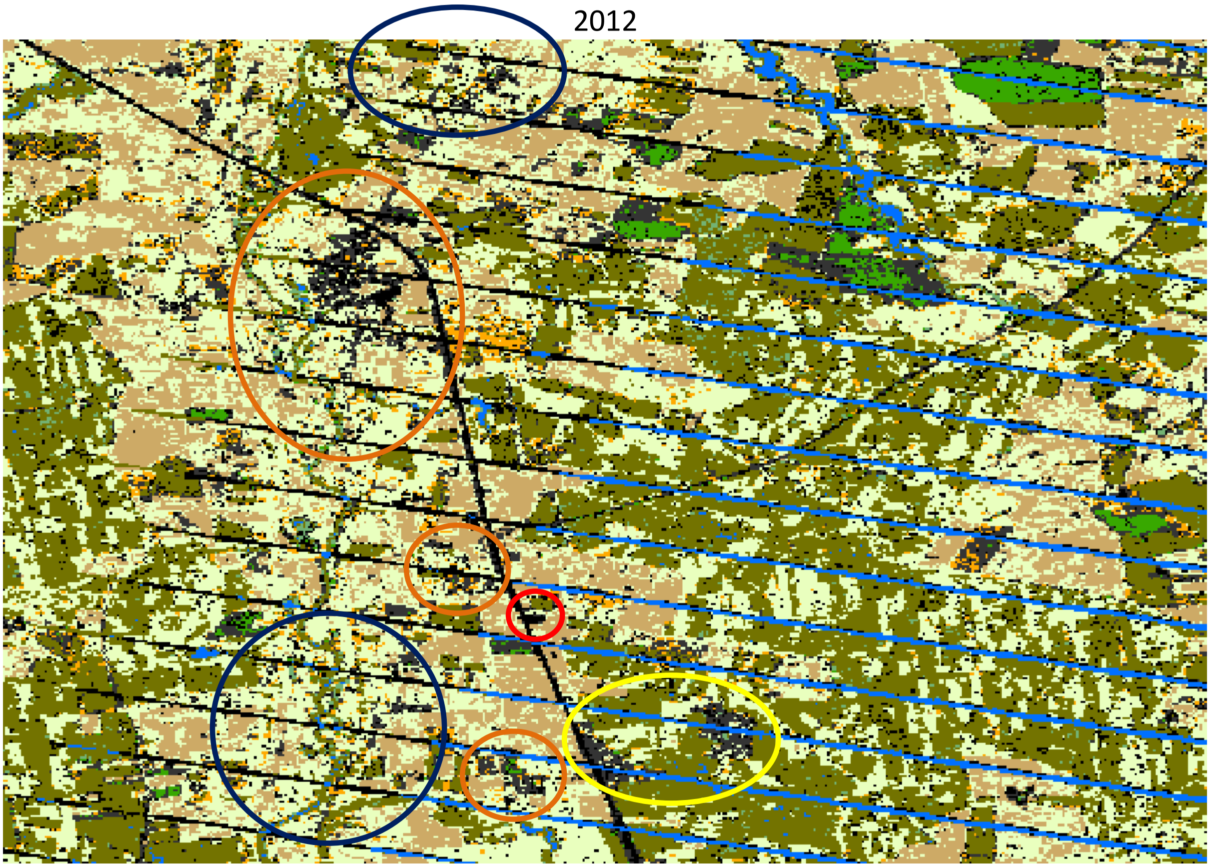
Emergence of urban area (red), densification (yellow), growth and densification (orange), growth and urban dispersion (blue), Sébastien Gadal, 2012

2001



Test zones of changes (white), Sébastien Gadal, 2012

2012



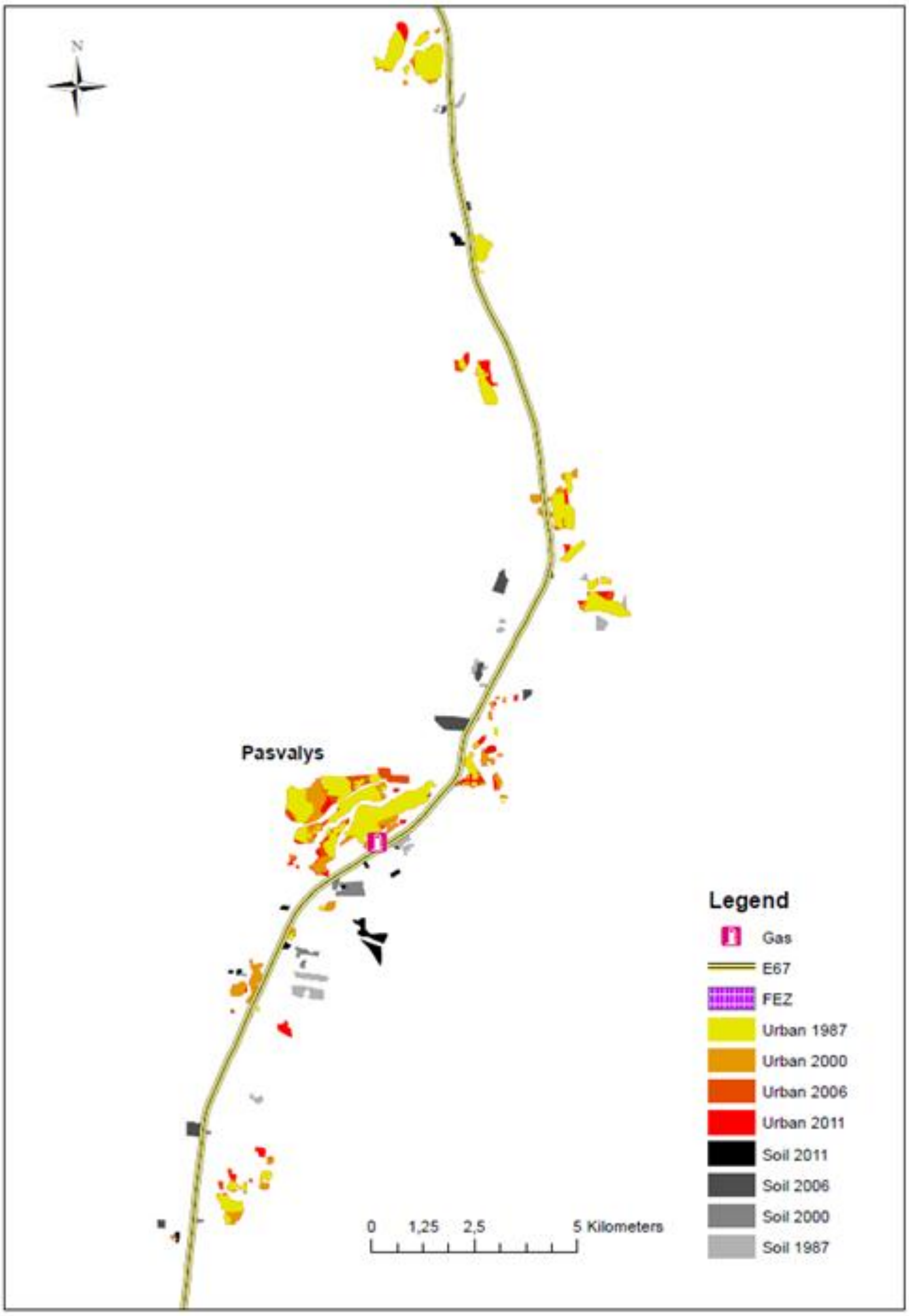
Emergence of urban area (red), densification (yellow), growth and densification (orange), growth and urban dispersion (blue), Sébastien Gadal, 2012

3.2.2. Examples of urban changes impacts recognition by remote sensing digital image analysis

Figure 26: Urban evolution of Pasvalys region (1987-2000)

Sébastien Gadal, smvg 11 group, Klaipeda University, 2012

Figure 27: Urban distribution of Pasvalys region in 2011



Sébastien Gadal, smvg 11 group, Klaipeda University, 2012

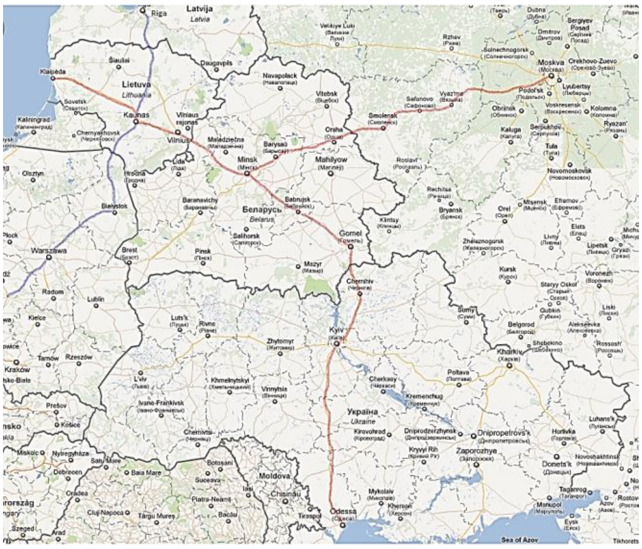
3.2.3. Geographic Analysis

Since the restoration of the independence in March 1991 and the collapse of the USSR, the transformation of political and economic regime, the lack of strategic planning, and the integration in the European Union affected the spatial dynamics and territorial change of Lithuania during the last twenty years: the massive emigration (officially 1.2 million Lithuanians for a population of 3 millions), the urban growth, the suburbanization, the gentrification, the rural land abandonment, and the exploitation of forest resources.

These societal and geographic changes can be associated with an emergent process of metropolisation at the regional and local levels. They have a limited impact on the transformation of the urban and territorial structures at the national scale, comparing to the local (city level) as for example Vilnius, Klaipeda and Kaunas.

The Klaipeda-Vilnius-Kaunas transportation corridor is the structural axis of development in Lithuania since the Soviet period. This strategic development corridor links Minsk, Moscow, Kiev and Odessa (Black Sea). Klaipeda is the only port in the Baltic Sea, which does not freeze during the winter. Lithuania has inherited with the collapse of the USSR a part of the West hinterland of the former USSR. It determines the economic geopolitics of the Lithuanian Republic with its neighbors, particularly with the Republic of Belarus. The importance of territorial organization by former Soviet Lithuania, a hinterland, as well as a development corridor, the lack of post-independence strategic politics of territorial development, as in Latvia, maintains geographically, structurally and spatially dependent economic market of the Russian Federation and CIS countries. The country struggles to shift or diversify its economic networks: 40% of the Lithuanian economy is dependent on the Russian market.

Figure 28: economic trade corridors in Lithuania



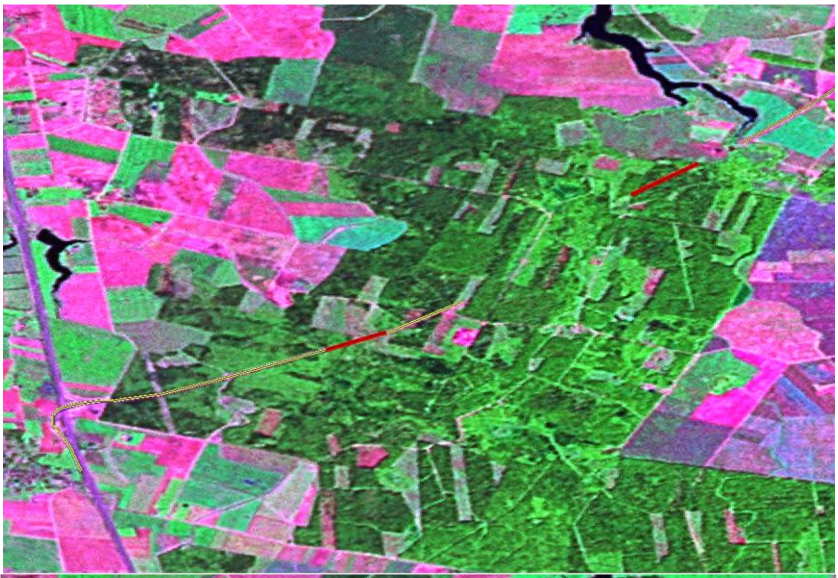
Sources: GoogleMap, August 18, 2011, field surveys, 2006, 2009, 2011. Blue: via Baltica axis of development planned by the European Union (Prague-Warsaw-Kaunas-Riga-Tallinn-Helsinki). Red corridor exchanges set up under the USSR. Phase of reactivation along an axis Klaipeda via Odessa-Kiev and Minsk (trans-Asian trade), Sébastien Gadal 2011.

The second corridor of development which has shaped relations and part of the Lithuanian economy since the Middle Ages, the Berlin-Warsaw-Kaunas-Riga-Tallinn, the ancient *Via Baltica*, is one of the strategic corridor of development officially recorded and supported by the European Union. Its importance to the intensification of trade for the European Union, Germany, Poland, Latvia, Estonia and Finland, or St. Petersburg is crucial as the TGV projects Berlin-Warsaw-Kaunas-Riga, etc. (the old route through the former Konigsberg, actually Kaliningrad is closed) (Gadal, 2011).

3.3. Road construction monitoring

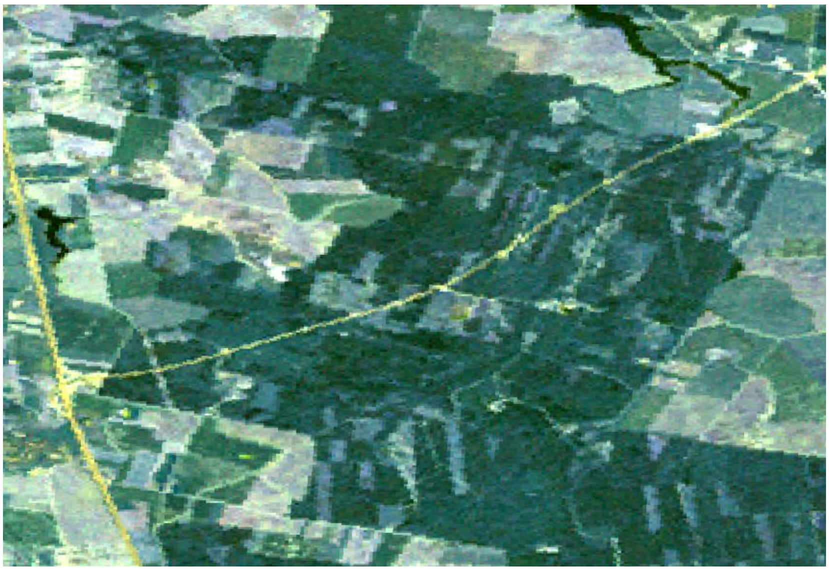
3.3.1. Digital analysis (Figure 29)

2000
(Yellow: constructed)
(Red: under construction)



2000
(Yellow: constructed)
(Red: under construction)

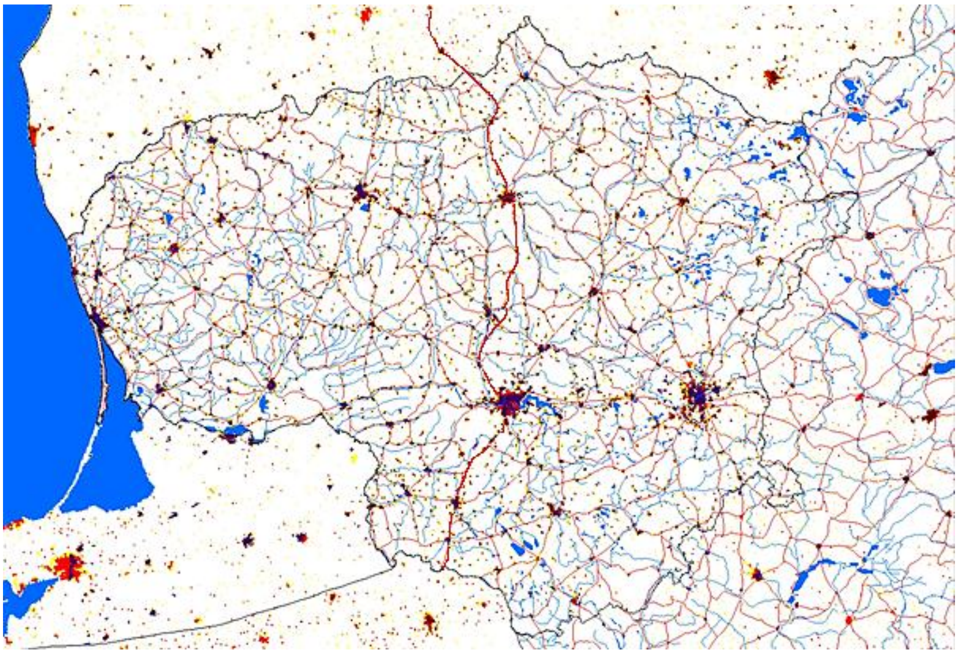
May 2001
(Yellow:
constructed)



Remote sensing monitoring allows detecting the level of road under construction, and the type of coating used (type of asphalt, road without asphalt, etc.). The road color gives the type of road coating used. According to the Landsat series images, as the beginning of the 2000, the building of the Via Baltica is not finished: Some segments of the Via Baltica are not finished or not yet built.

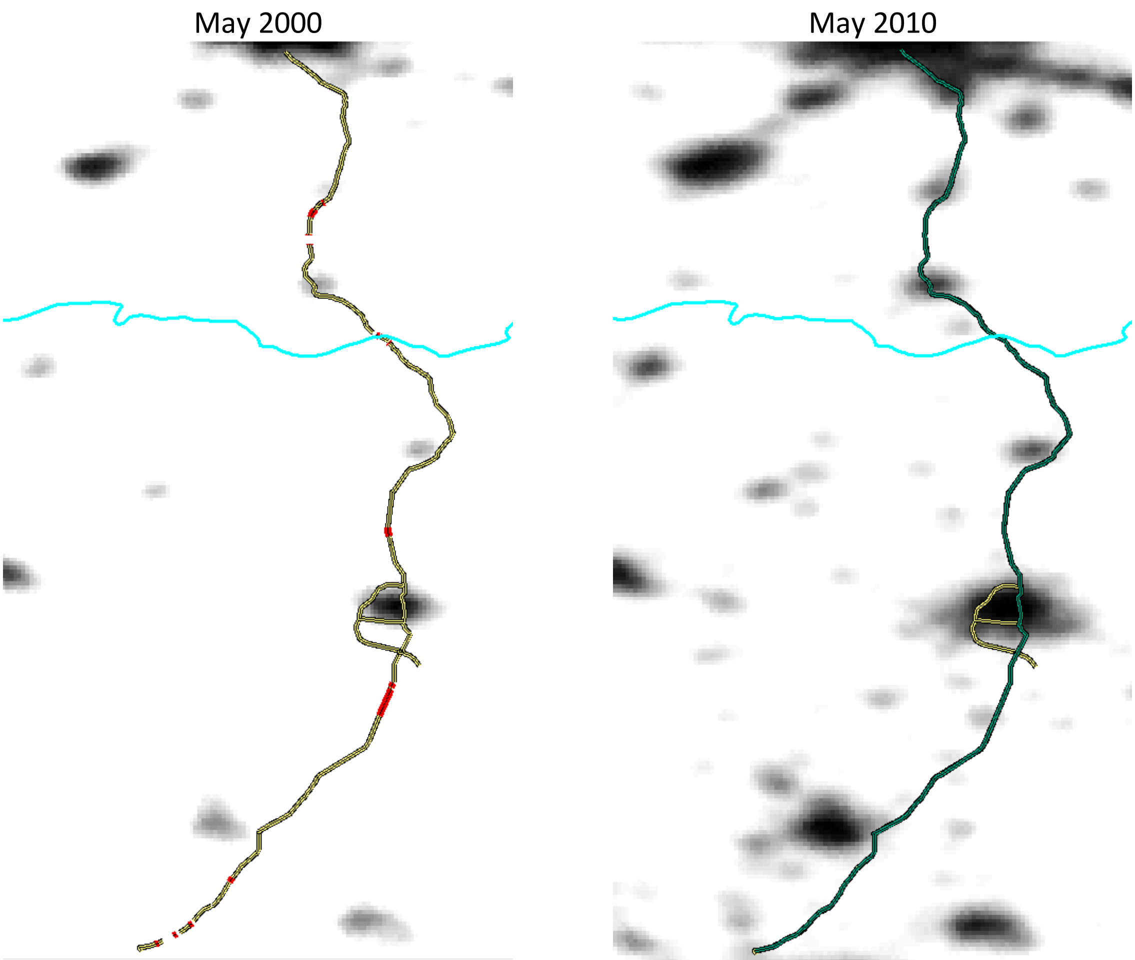
3.3.2. The Via Baltica under the regional urban transformations

Figure 30: Local growth of urbanization within the Via Baltica



Legend: Urban areas (1989) (black), Urban areas (2000) (red), Urban areas (2007) (yellow), Sébastien Gadal, 2009-2011.

Figure 31: Regional growth of urbanization within the Via Baltica

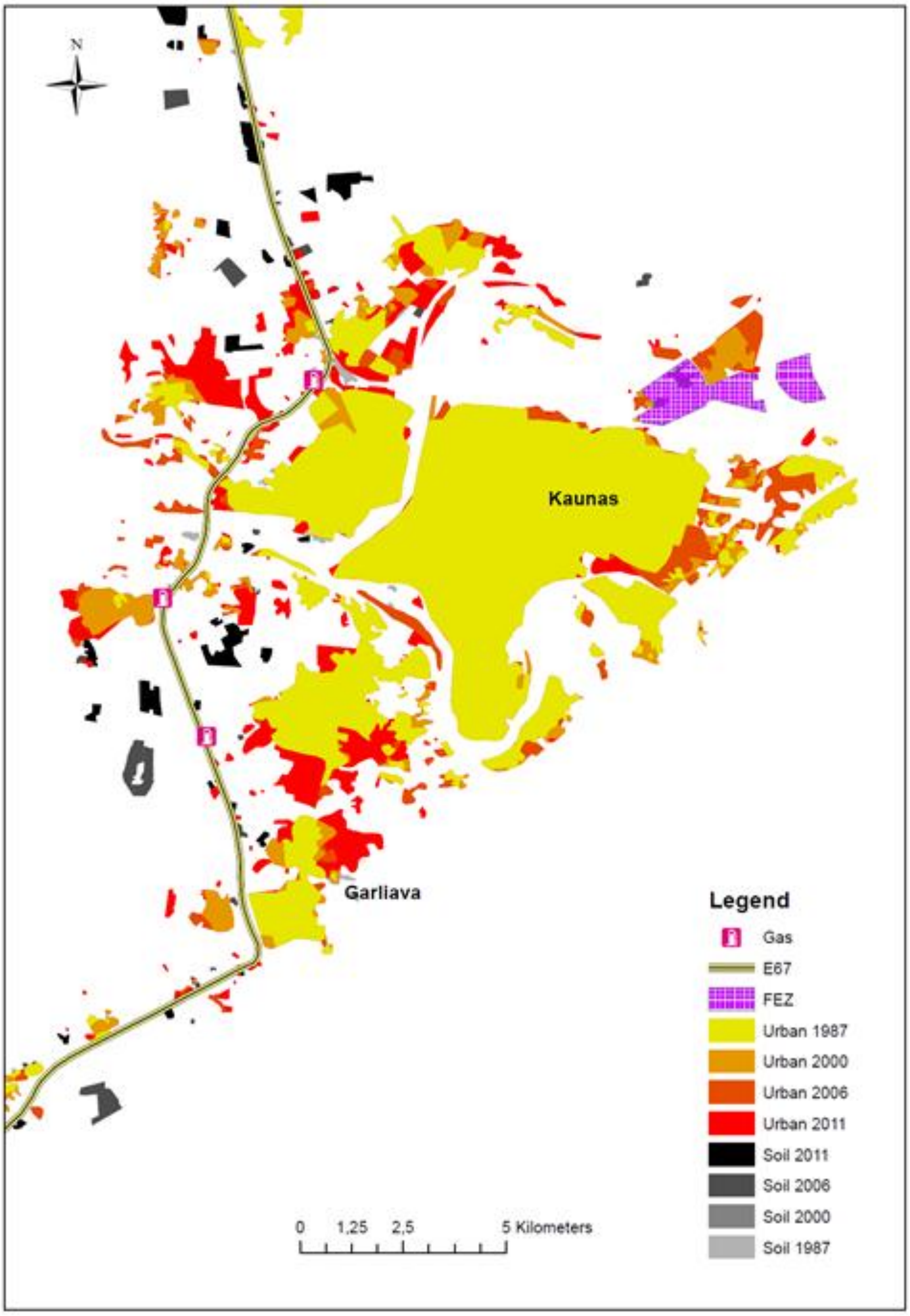


Sébastien Gadal, 2012

It is difficult to establish the impact of the Via Baltica on the urban growth at the local level. In regard to the regional level, the *Via Baltica* is an infrastructure reinforcing the dynamic of urban extensions and dispersion. In the hierarchic centralized organization of the urban Latvian territory, the Via Baltica is the major infrastructure of communication linking the towns to Riga in a radial spatial organization. It appears more as a corridor of development. In Lithuania, according to the territorial organization, the *Via Baltica* impact on the urbanization is more difficult to measure. The dense and dispersed territorial framework and network of medium and small towns and villages seems to limit the Via Baltica impact on the territorial organization. The urban growth measured by remote sensing within the Via Baltica since the end of the Soviet period is observed in the large part of the country.

3.3.3. The Via Baltica as local vector of local development (example of Kaunas)

Figure 32: Urban growth of Kaunas (1987-2000-2006-2011)

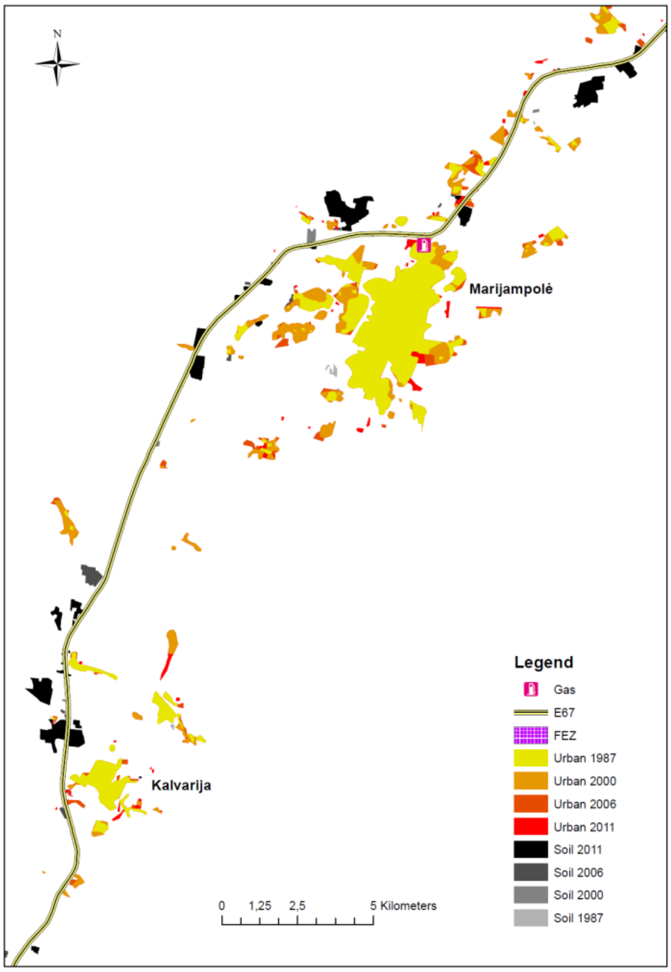


Sébastien Gadal, smvg 11 group, Klaipeda University, 2012

The digital cartography of the urban evolution of Kaunas shows the emergence of road urbanization since the 2000's within the *Via Baltica*. It is characterized by the building of new industrial zones (like for example, the FEZ), commercial zones, and the extension of former Soviet suburban areas as Akademija, Domeikava, Garliava and Raudondvaris. The localization, a crossing point between the two major networks of communications and exchange, and the industrial heritage from the Soviet period are the main factors of the road impacts on the urbanization in the context of metropolisation dynamics. The role of “driver” of the economic is linked with the presence of industrial zones implemented during the URSS, as for example Panevezys. The *Via Baltica* is also a strong support of territorial human development characterized by the urbanization and the metropolisation: the emergence of new suburbs or the growth of the existing former Soviet suburban areas is directly linked to the change of the lifestyle, the emergence of the middle class, the increase of the level of life, and the strong increase of the road car mobility.

The impact of *Via Baltica* on the local development, if it is narrower, on the middle cities as for example Marijampole; its influence concerns the emergence of commercial, industrial zones and suburbs in the framework of the metropolisation.

Figure 33: Urban growth of Marijampole and Klavarija (1987-2000-2006-2011)



Sébastien Gadal, smvg 11 group, Klaipeda University, 2012

Conclusion

The question of the territorial impact of the road corridor emerges with the research on the planning of rest areas location on the *Via Baltica.* The main impact is linked to the urban dynamics with the process of metropolisation. The process of metropolisation concerns large parts of the Lithuanian territory. It appears after the collapse of the USSR. But this major geographic phenomenon, changing the face of the territory, is rarely integrated in the strategic planning. The *Via Baltica* is an example of this lack. The Riga-Kaunas corridor should be one of the major axis of territorial development, and not only a space of economic flux disconnected of the spaces that it is crossing (a space of transit). The majority of road corridors are conceptualized by corridors of developments.

The acuteness of this problem is post-Soviet political and societal and the absence of strategy of territorial development and integrated territorial politics linked to the economic development.

There is a dichotomy between the reality of urbanization and urban development plans implemented by municipalities or the State: urbanization is guided by liberalism, theoretical frameworks and methods of Soviet planning who are in contradiction and out of step with the reality of spatial dynamics of metropolisation and urbanization.

The plan of development of the *Via Baltica* is exactly in the same point: an absence of strategy of development which can be driving the territorial and economic changes. Investments are limited to some cosmetic and superficial plans as the plan of rest areas within one of the major corridor of development and exchange network of the UE Baltic region.

In the absence of a real development policy at the national and regional levels, the territorial structure of the country has changed little. The spatial changes observed, measured and modeled by remote sensing, concern the regional and the local geographic levels. They are characterized by the urbanization: densification of the former Soviet blocks districts, extension and emergence of suburban areas.

Notes

Between the end of 1960 and 1991, the territorial grid of the Lithuanian territory generated a dense urban territorial structure of inter-connected urban villages and small cities, whose three territorial sets emerged, which in 1991, could be considered in process of metropolisation: the dipole Kaunas-Vilnius, Klaïpeda, the axis Šiauliai -Panevėžys: conurbation, suburbanization, etc. (Gadal, 2011).

In Latvia, the urban system developed during the Soviet period, it founded on the concept of "plain system of habitats", is based on an urban system arranged hierarchically on five levels (from Riga at the 564 urban villages) whose space distribution is determined by the transport and access time. The totality of the urban centers and villages had to be at three hours distance from Riga.

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