

Research Article

Analyses of Archival Cartographic Materials for Geomorphological Changes of River Channel

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In Lithuania, the old archival topographic maps of locations of small and medium scale and 1 : 10,000 scale contour photo plans were created on the basis of aerial images. The material of these scales provides documented records on the condition of the objects in the location and the landscape at the moment of aerial photography. Those maps can be used to restore the accurate topographic image of the terrain and buildings in 1945–1951 and in later years and perform the necessary topographic, photogrammetric, and geodetic measurements of the parameters of objects, to identify the location of objects and changes. This information is necessary for a variety of disputed property issues and for building farmhouses in reserves, in areas of forestry land parcels, and for assessment of changes in the landscape. Studies of landscape changes are needed for the assessment of renaturalization processes. This paper presents the geodetic method used for geomorphological changes at the channel of River Žalesa during the period 1942–2017, based on the collected archival cartographic materials: historical topographic maps from Archive of the Lithuanian State Company Land Fund, Land Information System, and land management projects and orthophoto maps from Lithuanian spatial information portal and free open-access Sentinel-1 satellite data from the Copernicus Open Access Hub.

1. Introduction

Nowadays, the impact of anthropogenic environment is important, and the landscape is going through major changes that may become irreversible over time [1, 2]. However, the opposite trend, namely, renaturalization processes, is also seen; these phenomena are observed and studied by scientists in many countries. Generally, the renaturalization process is identified as a geographic (geomorphologic parameters) change of abandoned areas into natural habitats [3–5], afforestation, and natural forest seeding in abandoned areas. Anthropogenic influences occur because of human activity and affect the environment.

Archival cartographic material modes from aerial photographs become the primary study target and a tool in cultural and historic analyses [6, 7]. Also, the orthophoto maps can provide valuable information about the object geometric changes in landscape taking place over time, its denaturalization and renaturalization. When comparing the local situation in archival-historical maps and orthophoto

maps with the current situation, one may see the trends of changes in the area, including locations of the river in different periods and changes in the river channel trends over time [8–13], and attempt to identify their causes. By this method, it is possible to establish changes influenced by anthropogenic factors, including the urbanization processes of the areas [1, 14, 15], and changes in the channels of rivers and streams as a result of land reclamation. This method can be applied to the monitoring of naturally ongoing renaturalization processes, the monitoring of changes of river channel, and planning river restoration processes [16]. Anthropogenic activities and renaturalization processes affect the location of river channel; human activities may affect changes in river channel more than natural causes such as drought, landslides, and floods [17–19]. In turn, changes in river channel can cause a variety of highly negative consequences for the environment, ecology, and landscape [19]. It is therefore important to characterize geomorphological river channel changes and select river for renaturalization processes. There are several geomorphological features: configuration, river channel width, braiding index,

and bed elevation [18, 19, 21]. These changes are clearly displayed in maps and aerial photographs [18]. But using digital archival cartographic materials, it is possible to identify some new features like river bend point place (with point coordinates), area of border that deformed from the river, and merger of the river branches (with point coordinates). In this case, by monitoring of both the landscape and river channel, orthophoto maps provide more information than topographic maps; however, information from orthophoto maps should be carefully processed to avoid misinterpretation of data. Data obtained from photos will better reflect the changes in the geography river flow and vegetation near the river. Currently, a method for mapping river geometric properties and geographic location using remote sensing (RS) is adopted. New RS techniques provide an abundant source of data at the large scale, which can be exploited for characterizing the status of rivers in an objective and coherent and geographical way. For this purpose, the RS sensor is used for the capturing of data about the geography of object or scene remotely. In the field of vegetation and water body mapping, the most commonly applied data are from satellites Sentinel-1 and Sentinel-2 [20]. The satellite data access archive is full, free, and open in the Internet (example, the Copernicus Online Data Access Hub) [20].

The aim of this study was to use new geomorphological features for identifying the river channel changes from archival cartographic materials of different periods and remote sensing data. The geodetic method does not require the specific hydrological or geomorphological knowledge.

2. Materials and Methods

2.1. The Archival Cartographic Materials in Lithuania. In order to record the condition of objects and to monitor the geometric changes, it is proposed to use the following archival cartographic material data sources: contour photo plan or geographic location of different period, scale 1:10,000 (archive of the Lithuanian state company Land Fund); topographic maps of different periods of the geographic location of the scale 1:25,000 or 1:50,000 (Land Information System (LIS)) data from on-line (<http://www.geoportal.lt>) [22]; and land management projects of location of different periods (LIS data). The Lithuanian State Land Fund archive keeps aerial photographs compiled for the country's mapping, based on the flight details of Soviet military aviators in 1945–1948 and in 1951–1952, and contour photo plans on a scale of 1:10,000 drafted from them. During the period 1945–1948, photographs of locations were made using a camera with a lens of focal length of 154 mm. Format of aerial reverse photographs is 23 × 23 cm. The scale of aerial photographs depended on the flight altitude of the aircraft and ranged from 1:18,500 to 1:22,000 (Figure 1) [23].

In 1951–1952, aerial photography was performed by a civil organization using a camera with a focal length of 152 mm. The format of the aerial reverse photography is 23 × 23 cm. Aerial photography did not cover the whole territory of Lithuania. No images were made on the seaside between Klaipėda and Šilutė, the border between Vilkaviškis,



FIGURE 1: Fragment of the contour photo plan N-34-72-G-b-1 of 1953 made on the basis of the flight of 1946 (source: the Lithuanian State Land Fund archive).

Kybartai, and Vištytis, and in significant areas around Kaunas, Vilnius, Šiauliai, and other major cities. Contour photo plans were created by mounting transformed aerial photograph and by adhering to technology, depending on the requirements and accuracy. The root-mean-square error of the position of the main outlines of photo plans M1:10,000 is ± 0.24 – 0.47 m (in the area from 2.4 m to 4.7 m) and zoomed to 1:5,000 scale plans— ± 0.31 – 0.54 m (in the area from 1.5 m to 2.5 m). Zoomed 1:5,000 scale land management projects were drafted for land reclamation works. Photo plans have the coordinate network of the Soviet system of coordinates KS-1942 and are decrypted; namely, local objects in the plans are marked with conventional topographical signs that are valid at the time. Aerial photography slides of Soviet military aviators of 1945–1948 are archived in the archive of the Lithuania State Enterprise Land Fund [24].

After 1960, upon introduction of the new coordinate system (KS-63) in 1963, the use of the KS-42 coordinate system and the photo plans made in this system has been prohibited. As a result, the pending topographic mapping work on a scale of 1:10,000 was suspended. Coordinates of the points of the geodetic base of the territory had to be transformed to the new system, and it lasted until 1967. On completion of the conversion work, the fifth company of the Central Board of Geodesy and Cartography (VGKV) started to redraft the Lithuanian maps in the KS-42 coordinates system on the scale of 1:10,000 into the new system of coordinates (1954–1964). Recomposed maps were printed by repeating the old content. Drafting of topographic maps on the scale of 1:10,000 started in 1971 and covered nearly the entire territory of Lithuania by the end of the Soviet period. While newly creating a topographical map, the area was photographed twice. Aerial photography of smaller scale and longer focal distance was taken for photo plans, and photos of larger scale and shorter focal distance for stereoscopic relief images were taken. For aerial photography, aircraft were fitted with gyrostabilizers (to ensure the stability), and readings of radio altimeter and statoscope were registered. Aerial photo routes were oriented towards the east-west direction, and the format of all aerial reverse photographs was 18 × 18 cm. When preparing a topographic map or renewal of the current use of geodetic points, coordinates of

points necessary for photo plans were determined analytically, by preparing single-route aerial spatial photo to triangulation chains based on contour signs. Photo plans were produced by optical assembly with simultaneous aerial transformation by dividing the transformed area into zones where the terrain heights range within 10 m [23].

Aerial photography was also used to make topographic 1:25,000 scale maps. The uniform 5 m step was used to indicate terrain. Various technologies were used to update the terrain drawing: in Klaipėda region, horizontals and heights of the same scale of the German map were transferred, the contents (terrain) of old maps were used on the maps of the mid- and south Lithuanian borders, combined topographic image using photo plans and measurements with the telescopic sighting alidade, and the topographic drawing board was used entirely for part of the current Lithuanian territory in 1949–1950. The new image for the entire territory of Lithuania was completed only in 1959 [22].

The National Land Service under the Ministry of Agriculture founded the Lithuanian spatial information (LEI) portal—the state information system for the centralized provision of spatial data sets and related metadata services to users (<http://www.geoportal.lt>). Currently, the LEI portal offers viewing and downloading of the following historical topographic maps: coordinate system of 1942 M 1:10,000–81 pcs.; coordinate system of 1963 M 1:10,000–3844 pcs.; coordinate system of 1942 M 1:25,000–1989 pcs.; coordinate system of 1963 M 1:25,000–833 pcs.; coordinate system of 1942 M 1:50,000–45 pcs.; and Lithuanian coordinate system of 1994 LKS-94 M 1:10,000–110 pcs. The LEI portal had in total 6,902 units of historical topographic maps, and also digital raster orthophoto maps ORT10LT 1995–2001; 2005–2006; 2009–2012 of 2012–2013 and 2015–2016 are offered in the data layers of the LIS.

2.2. Experimental Object. The water source of state significance—River Žalesa in Vilnius (capital of Lithuania) district—is analysed. The river belongs to the basin of small tributaries of the river Neris (the Neris). This river has historical significance. In old Baltic and Slavic word outlook, river took a really important place, along the shores; until now, there are left a lot of burial places, barrows, sacred oak woods, and mythological stones. In the Neris river landscape developed the state of Lithuania. It is known that in the Middle ages existed the land of Neris. Next to Neris, there is the mountain of Gediminas and the Vilnius castle location. The river Žalesa is the right inflow of the river Neris. The length of the river Žalesa is 18.8 km, and the catchment area is 9.2 hectares. Also, the river flows from the northern Gulf of Lake Žalesas (Pikeliškiai) (Figure 2).

Liubavas Manor was founded near River Žalesa, in the northern districts of Vilnius. Currently, Liubavas Manor has 10 surviving buildings, while a part of the former ponds and greenery, and the palace is not preserved.

The separable river channel leads to Liubavas Manor mill, which was first mentioned in 1727, rebuilt in 1902, and refurbished by establishing the museum in 2011 (Figures 2 and 3).

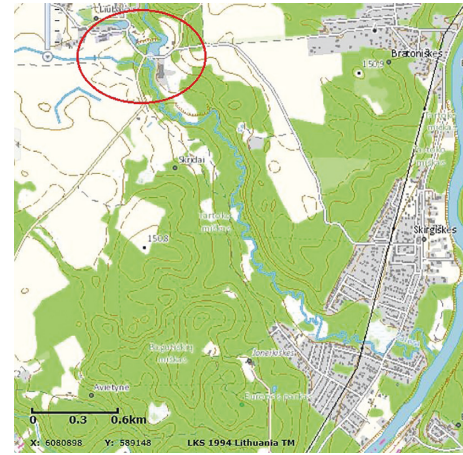


FIGURE 2: River Žalesa (the mill-museum in the red circle) (source: <http://www.geoportal.lt>).



FIGURE 3: Liubavas mill-museum (source: https://lt.wikipedia.org/wiki/Liubavo_dvaras).

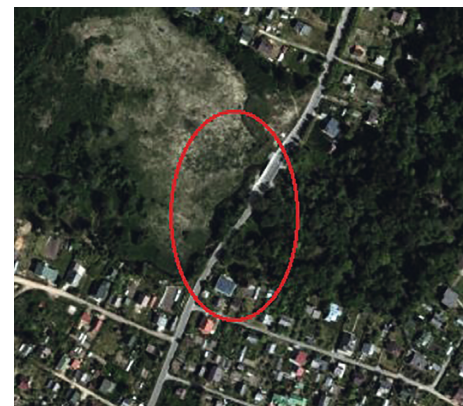


FIGURE 4: Analysed river section in the digital raster orthophotographic map (source: <http://www.geoportal.lt>).

Because the length of the river is 18.8 kilometres and watershed area is 97.1 square kilometres, only part of the river in the village of Skirgiškiai will be studied. The length of the analysed river section is about 250 metres. The analysed part of the river is parallel to the asphalt road (Bagutiškių street) (Figure 4).



FIGURE 5: Digitized section of River Žalesa is represented in the topographic map of 1950 (source: <http://www.geoportal.lt> and authors' digitalization).

2.3. Observation of the Geomorphological Changes of River Channel Based on the Archival Cartographic Materials.

Archival cartographic materials are for the analysis [20, 22]:

- (1) Topographic map of 1950, M 1 : 25,000 (nomenclature-N-35-39-G-a)
- (2) Topographic map of 1966, M 1 : 25,000 (N-35-39-G-a)
- (3) Topographic map of 1972, M 1 : 25,000 (C-45-24-B-g)
- (4) Topographic map of 1984 M 1 : 10,000 (C-45-24-B-g-3)
- (5) Topographic map of 1986 M 1 : 25,000 (C-45-24-B-g)
- (6) Orthophoto maps (ORT10LT) were made in 1995–2001, 2005–2006, 2009–2010, and 2012–2013 M 1 : 10,000
- (7) Satellite Sentinel-1 data 2017-11-04.

Archival cartographic data were from the online version of LEI's website, <http://www.geoportal.lt>. Topographic material includes a sixty-one-year period; therefore, the study shows how the main topographical elements and geography of the analysed object were changing in six decades. Orthophoto maps of 4 different periods were used for additional studies.

These maps of four different periods show clearly noticeable changes in the river channel and also display features of topographic mapping.

To monitor the geomorphological changes of the water shore, digitization of the part of the river channel in the topographic maps was performed using the GeoMap software. Digitization results are presented in Figures 5–8. In Figures 5–7, we have seen that the river configuration remained almost unchanged from 1950 to 1972. Larger changes were observed in the mapping data of 1986 (Figure 8).

The periods from 1955 to 1980 were the most intense years in Lithuania when the wetlands were being drained. In this period, there was drained 2.8 mln. ha. of land utilities or 80 percent of farmland. Many natural rivers of Lithuania were made into straight canals as parts of the drainage system [25, 26].

To accurately assess the geomorphologic changes of the river banks, six sections of the river channel of the basin were chosen, marked in the topographic map, and analysed (Figure 9):

- (i) River bend (set bend point coordinate) (sections 1 and 5 in the river channel)

- (ii) The river channel towards the resulting water body (set width of the river channel) (section 2 in the river channel)
- (iii) Border that deformed from the river (set body area) (section 3 in the river channel)
- (iv) Merger of the river branches (set point coordinate) (section 4 in the river channel)
- (v) Estuary (set point coordinate) (section 6 in the river channel).

Results of the sections measurement are provided in Table 1.

The river sections presented in the map of 1986 have completely changed (100%) by both the river channel curves and the width (Figure 8). The river channel is narrowing and is marked with a single line, while according to the requirements of topographical maps, one line indicates a river no wider than five metres. Also, throughout the period in question the dimensions, shape, and area of the river pond are changed (section 3 of the river channel (Figure 9; Table 1)). Points of 1 and 4–6 sections of the river channel are shown (Figure 9; Table 1). In the topographic maps of 1950 and 1986 years, there was established x, y coordinates (in the coordinate system LKS-94). The calculated coordinate changes are in Table 2. The section points of coordinate changes in x -axis range from -19 to -105 metres and in y -axis from -9 to -73 metres. It can be stated that such a geometric change in the river channel was due to extensive human activity, for large areas of ameliorated land, construction of residential buildings, new roads, farming, and forests not felled at the river (Figure 10) [27]. Archival cartographic material shows that within thirty-six years, the number of residential houses around the river grew, forest areas expanded, and new roads were built (1986). The topographic plan of 2011 shows a newly built culvert under the road and the bridge over the wider river channel. The landscape has undergone major changes that, over time, may become irreversible [5]. The high urbanization rate stimulates renaturalization acting, in the opposite direction. A comparison of the details of digital raster orthophoto maps of 1995–2013 shows no big changes in the river channel, but the drying swamp is perfectly visible (Figure 11). The orthophoto maps of 2005 does not show the pond presented on the topographic map of 1986. The orthophoto maps of

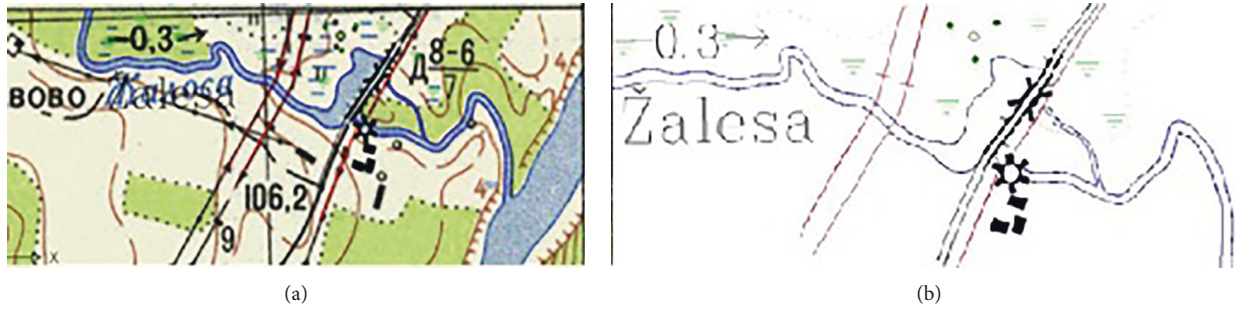


FIGURE 6: Digitized section of River Žalesa is represented in the topographic map of 1966 (source: <http://www.geoportal.lt> and authors' digitalization).



FIGURE 7: Digitized section of River Žalesa is represented in the topographic map of 1972 (source: <http://www.geoportal.lt> and authors' digitalization).



FIGURE 8: Digitized section of River Žalesa is represented in the topographic map of 1986 (source: <http://www.geoportal.lt>).



FIGURE 9: Section of River Žalesa is measured in the topographic maps (source: 1984 year topographic map. <https://www.geoportal.lt/geoportal>).

TABLE 1: Results of the river line change.

Analysed maps (years)	Sections of the river channel					
	1	2 (m)	3 (m ²)	4	5	6
	X Y (m)			X Y (m)	X Y (m)	X Y (m)
1950	60,78,224 5,87,547	8	7,199	60,78,085 5,87,928	60,78,151 5,88,012	60,77,992 5,88,080
1966	60,78,224 5,87,547	8	6,209	60,78,074 5,87,931	6,08,147 5,88,022	60,77,987 5,88,088
In 1950–1966, the mill was included, the pond area changed, and the place of the merger of branches and the place of the tributary joining the river Neris changed						
1972	60,78,224 5,87,546	9.5	6,798	60,78,074 5,87,931	60,78,147 5,88,015	60,77,987 5,88,083
1984	60,78,242 5,87,578	4	11,741	60,78,140 5,87,943	60,78,250 5,88,043	60,78,085 5,88,153
1986	60,78,243 5,87,578	3	11,864	60,78,148 5,87,937	60,78,256 5,88,041	60,78,085 5,88,153
In 1966–1986, the mill was removed, the river bend location changed, the river narrowed, the pond was large, and the place of the tributary joining the river Neris changed.						

TABLE 2: Changes in the section of the river channel.

River bank section	1950 X/Y (m)	1986 X/Y (m)	Difference dx/dy (m)
1	60,78,224/5,87,547	60,78,243/5,87,578	-19/-31
4	60,78,085/5,87,928	60,78,148/5,87,937	-63/-9
5	60,78,151/5,88,012	60,78,256/5,88,041	-105/-29
6	60,77,992/5,88,080	60,78,085/5,88,153	-93/-73

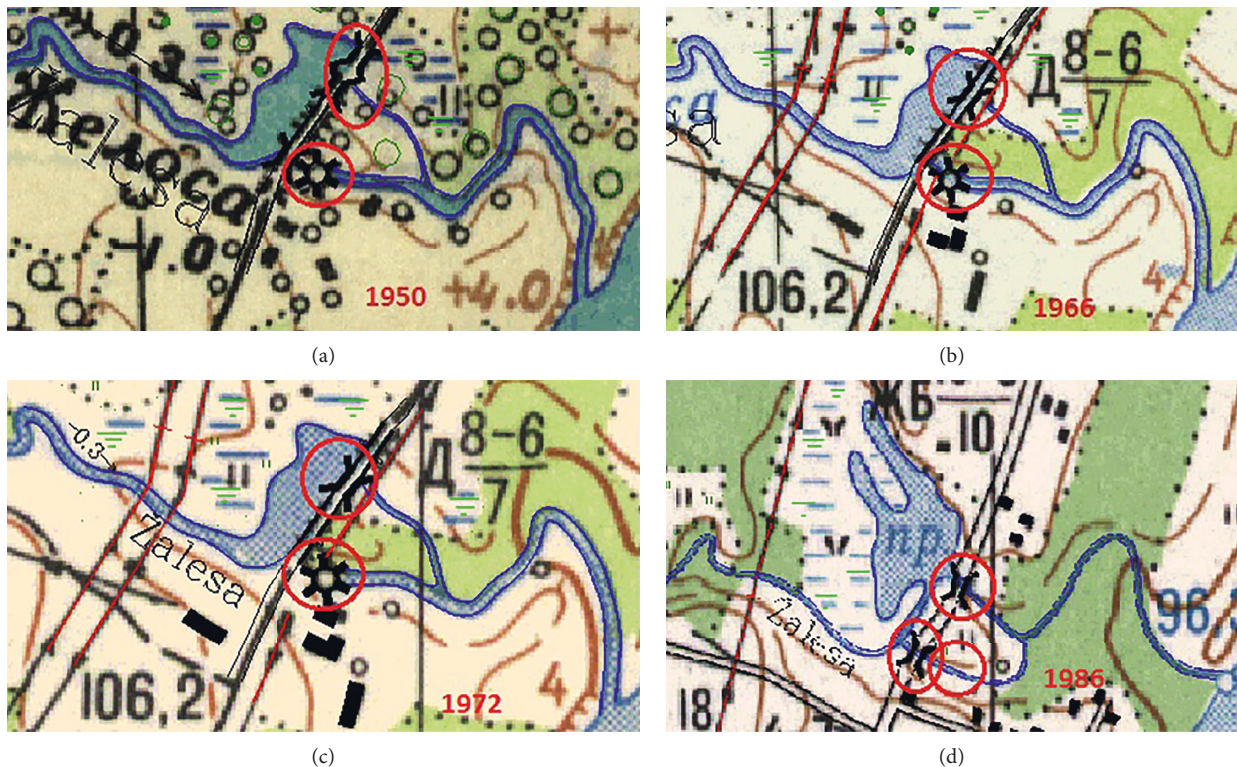


FIGURE 10: Signs of land drainage, urbanization in the old topographical maps (source: <http://www.geoportal.lt>).

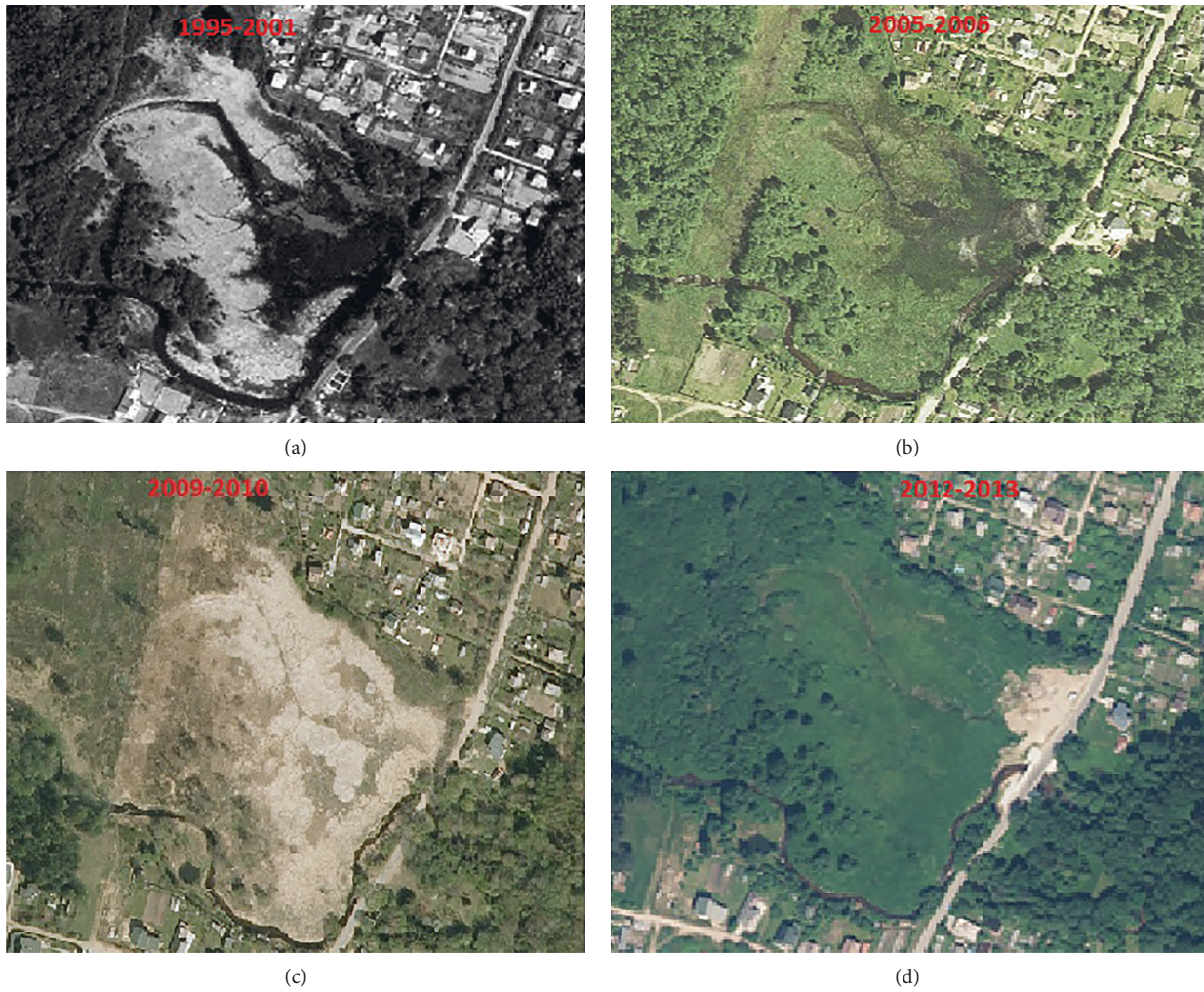


FIGURE 11: Digital raster orthophoto maps (source: <http://www.geoportal.lt>).

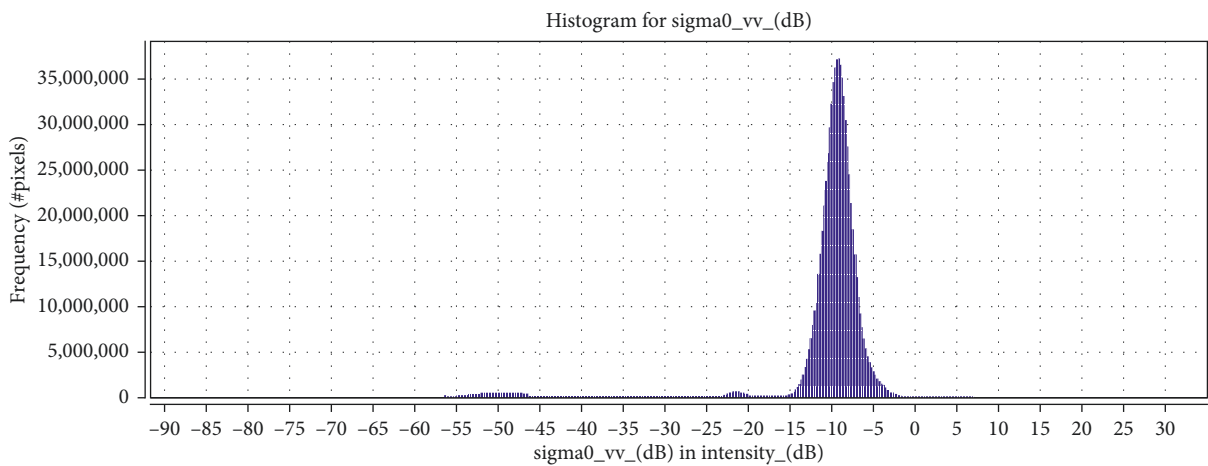


FIGURE 12: Computing histogram (source: authors).

2009–2010 clearly shows tenuous vegetation and deforestation. Often, scrubs replace the felled forest—the area turns into a desolate land. All orthophoto maps clearly show developing Skirgiškiai village near the river.

The river channel data were performed in the satellite Sentinel-1 Ground Range Detect (GRD) level 1 in 20×22 m resolution (2017-11-04), using the SNAP open-source software. The data are calibrated, spectra-filtered, and terrain-corrected.

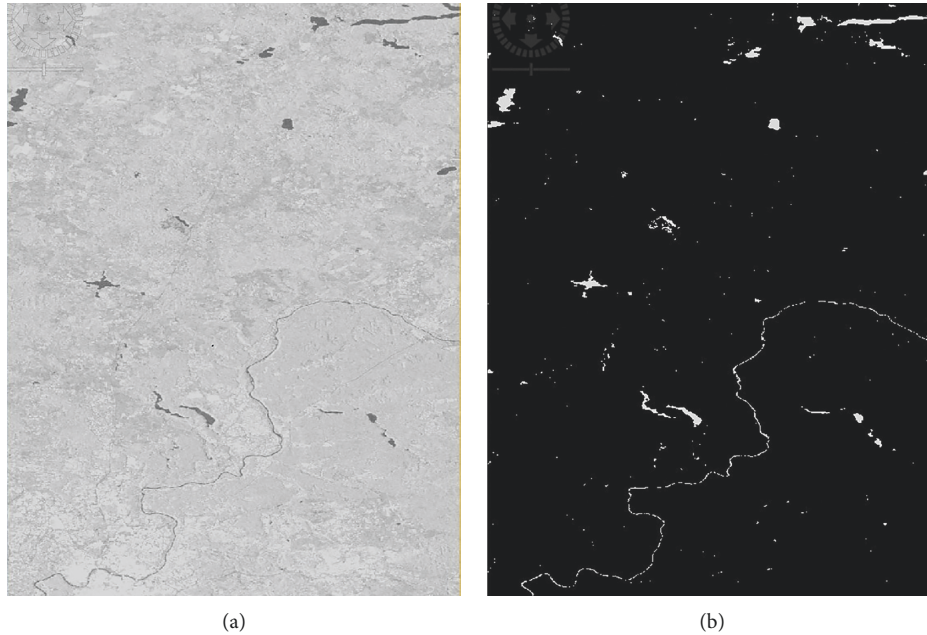


FIGURE 13: The river channel in the satellite data: (a) band-VV polarization data and (b) new river channel math band (source: authors).

The polarization histogram band-VV is computed into the decibel units. The results are presented in Figure 12.

Low pixels number shows that the surface is of low reflectivity (-15 db). We created water body information placing it into the new math band <-15 db. The information about the river channel with width more than 20 m is shown in the Figure 13. Because of low resolution of satellite data, the water source of River Žalesa is not visible in Figure 13(b).

3. Conclusions

- (1) According to archival aerial photos, it is possible to restore the local geographic situation over previous years, the condition of land parcel boundaries, buildings and other objects, and to measure and document them; however, special photogrammetric equipment is required for such work.
- (2) Details of aerial photos of early years can be effectively used in dealing with legal matters of land and other issues of real estate cadastre and property. It is advisable to use original archival aerial photos (aerial negatives and aerial photo images). These data are stored in the archives of the Lithuania State Enterprise Land Fund.
- (3) New geomorphological features were integrated into the river channel changes analysis:
 - (i) River bend point coordinates
 - (ii) River channel towards the resulting water body (the set width of the river channel)
 - (iii) Border that deformed from the river (the set body area)
 - (iv) Merger of the river branches (the set point coordinate)
 - (v) Estuary point coordinates.

These features could be measured by geodetic methods or identified in the archival cartographic materials.

- (4) Analysis of the short geometric changes in the water body (River Žalesa) based on the archival cartographic material was performed. The following were determined:
 - (i) The examined section of the river during the period 1950–1966 changed by 50% is bed straightened.
 - (ii) During the period 1966–1972, the river changed by 10%.
 - (iii) During the period 1972–1986 (fourteen years), the river changed by 100%. It can be concluded that such big changes occurred because of the intensely done drainage work and drained swamps.
 - (iv) The topographical maps of 1950–1986 show most changes to the water body formed near the river (pond); during the entire period (thirty-six years), the pond configuration changed by 100%, it dried out.
 - (v) The mill was partially destroyed in 1986 and restored in 2011.
- (5) Contour photo plans on a scale of 1 : 10,000 made on the basis of the aerial photo are stored in the archives of State Enterprise Lithuania Land Fund. The researcher suggests that placing the aerial photo material and photo plans in the digital form to the Land Information System would be easily available to consumers.
- (6) River Žalesa is not visible in the 20 m resolution satellite data. Therefore, the satellite data have to have higher resolution to identify the water channel successfully.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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