ISSN: 1857-9833
UDC: 55

# ACTA GEOBALCANICA

volume 5 | issue 2 | pp. 43-124 | 2019

# ACTA GEOBALCANICA

**Online-ISSN:** 1857- 9833 **UDK:** 55 **DOI:** https://doi.org/10.18509/AGB.2015

***Publisher:*** *Geobalcanica Society*
info@geobalcanica.org





Language: English | Papers are available on-line on: www.acta.geobalcanica.info

**CONTENTS:**

ACTA GEOBALCANICA
5-2, 2019, pp. 43-46

# IN MEMORIAM: PROFESSOR DR. GHEORGHE ROMANESCU

DOI: *https://doi.org/10.18509/AGB.2019.06*
UDC: *929Romanescu, G.*

**Alin Mihu-Pintilie[1], Cristian Constantin Stoleriu[2]**

*[1]Institute for Interdisciplinary Research - Science Research Department, Alexandru Ioan Cuza University of Iasi (UAIC), Romania*
*[2]Department of Geography, Faculty of Geography and Geology, Alexandru Ioan Cuza University of Iasi (UAIC), Romania*

corresponding author: mihu.pintilie.alin@gmail.com

submitted: *15.12.2018*
accepted: *25.12.2018*
published: *18.01.2019*

**Abstract**
A great sense of loss and sadness marked the recent death of the great geographer Gheorghe Romanescu who passed away lightning on his way at his home in Iasi, the Romania on October 3, 2018 after a long battle with his weakened heart. Professor Dr. Romanescu was a highly respected member of the international Earth Science community, who devoted his life to understanding and describing the global issues of geography, especially in the field of hydrology, remaining highly active in his domain until the end of his life.

Gheorghe Romanescu was born on September 1st, 1959 in Malcoci (Tulcea County, SE Romania), a small village from Dobrogea, where he spent his childhood learning how to swim in Sf. Gheorghe branch or exploring the water labyrinth of the Danube Delta. Until the age when he had to leave to the port of Tulcea to attend high school studies, he was already known for wandering the banks of the Danube, a land of reeds and willows inhabited by an impressive ethnic and cultural mosaic. Due to the proximity to the water and nature, after high school, he attended the Faculty of Biology, Geography and Geology, specialization of Geography in French within Alexandru Ioan Cuza University of Iași graduating in 1985. Between the years 1985 – 1991 he returned to the port of Tulcea and taught Geography at the Industrial High School no. 4 (1985 – 1986) and at Gymnasium school no. 5 (1986 – 1991). The Revolution and the fall of the Communist regime in December 1989 found him on the Danube's cliff armed with an automatic pistol without a loader defending the city's heritage buildings from ”imaginary terrorists”. This memory was recalled every time among different circles of friends describing those moments as a “short military service”.

The scientific interest of Gheorghe Romanescu in Earth sciences and water studies, apparently from an early age, led him to return to the academic environment in Iasi, just 6 years after graduating the geographic courses of the oldest university from Romania. Thus, between 1991 and 1996 he worked as a scientific researcher within the Geography team of the Romanian Academy. At the same time, in 1994 he became a doctor in Physical Geography at the Institute of Geography in Bucharest, with his paper work about the *Danube Delta, a morpho-hydrographic study* under the scientific coordination of Prof. Dr. Petre Gâștescu, one of the pioneers of the Romanian Limnology. This achievement was followed by a period of extensive research in fields of study related to deltaic and coastal hydro-morphology. Since 1995, when he was still a young researcher, and until 1998, following his interest in global water studies, he completed three postdoctoral studies: 1995 - Sedimentology and Seacoast Geomorphology, Oceanography Institute, Southampton (UK); 1996 - Limnology, Konstanz University, Konstanz (Germany); 1998 - Geomorphology and Hydrology, Sorbonne I University - Paris (France). In 1998, after the international experience on the shores of the Atlantic Ocean and the Alps, he transferred to the Department of Geography within the Faculty of History and Geography of the Stefan cel Mare University of Suceava, where he initially worked as Lecturer and later as Associate Professor until 2003. After acquiring a significant research experience and as an achievement of the scientific results of the last 10 years, in 2003 he transfers definitively to the Faculty of Geography and Geology, the Department of Geography of Alexandru Ioan Cuza University in Iasi, where he served as Professor until end of life.

Thanks to a diligent research work, as well as an unwavering passion for the exploration of the Earth, Professor Gheorghe Romanescu has made numerous contributions, both professional and didactic, to the development of modern Romanian Geography through significant studies in the field of Hydrology, Oceanography, Geomorphology (coastal dynamics, natural hazards, sedimentology of lacustrine complexes, etc.), Geo-archaeology and Wetlands. In the last 15 years (2003 – 2018) he taught 35 university courses (e.g. Hydrology, Oceanography, Water Geography of Romania, Limnology, Hydrological Risks, Black Sea Geography, Hydrology of Delta and Estuaries, Seaside Geomorphology, etc.) and supported 28 practical works and university seminars (e.g. Hydrology and Oceanography, Limnology, Water Geography of Romania, Hydrological Risk Assessment, Black Sea Geography, Hydrology of Delta and Estuaries, Hydrographic and Coastal Network Development, Hydrotechnical Arrangement of River Basins, Tourist exploitation of coastal and delta regions, etc.).

**Figure 1.** Professor Dr. Gheorghe Romanescu, Avachinski volcano, Kamchatka – 2014

Gheorghe Romanescu was an excellent speaker, a brilliant, enthusiastic and devoted researcher, a remarkable professor and an intellectually rigorous scientist characterized by the highest standards of personal and professional integrity. One of his key features was the ability to see the big picture, never losing sight of fine details. Since the beginning of his career, he has realized that water will become the most important socio-economic problem of humanity, thus stimulating his interest in raising and developing the study of water resources from an interdisciplinary and transdisciplinary perspective. From this point of view, he was one of the pioneers of the wetlands study in Romania and strengthened the cooperation in the field of hydrology in Europe. With his active and field-focused mind, he managed to connect the classical hydrology studies and GIS analysis, corroborated with information technology and mathematical statistics, always resorting to self-learning when he could not find anyone to show the link to a new discipline!

Perhaps the most representative professional characteristic of Professor Gheorghe Romanescu was scientific activity. He is the author of 51 courses and university books, including 12 books and book chapters published abroad. Here are worth mentioning the treaties *The tourist potential of coasts and deltas. A look at the romanian coastal areas*, *Geomorphological Impacts of Extreme Weather. Case Studies from Central and Eastern Europe*, or *Limnology of the Red Lake, Romania.*

*An Interdisciplinary Study*. He also published 39 university courses and books in Romanian: *Land Hydrology, Oceanography, Limnology, Inventory and Typology of Wetlands and Deep Waters in the Central Group of the Eastern Carpathians*, so on. Nevertheless, he is the author of 152 articles published in international journals and 135 articles published in national journals. From this perspective, with 542 references in ISI quoted papers and several other thousands of citations in scientific journals indexed in other international databases and monographs, researcher Gheorghe Romanescu will remain one of the most cited Romanian geographers of all time, both at national level, but especially at international level.


**Figure 2.** Photos around the world from the personal archieve of the Professor Dr. Gheorghe Romanescu: a. Scientific Expedition to the Andes, Altiplano – March 2008; b. Tierra del Fuego, Patagonia – Expedition "Ushuaia 2002"; c. Scientific Expedition to Kamchatka, Russia – June-July 2014; d. Expedition to Australia – July-August 2006.

In addition to being a very relevant reviewer and a passionate about the scientific literature, Gheorghe Romanescu has personally organized 15 sessions of scientific communications in prestigious Romanian institutions, moderated 55 national scientific sessions or under the aegis of international fora, and was associate editor / member of 43 scientific committees of prestigious scientific events, including the international scientific committee of Geobalcanica. He was also a member of 165 editorial committees of journals and specialized publishing houses as well as a scientific coordinator of 27 specialized books published at national and international publishing companies. As a result, throughout his life, he has received 35 national and international awards and prizes as recognition of his tremendous contributions to water research. Among these, we can mention the *Umwelt und Wohnen*, *Gold Medal* in 2012, 2014, 2015, and 2016 in the *EUROINVENT salon*, or the *Book of the Year 2013* offered by the Romanian Geographical Society.

From an administrative perspective, between 2007 and 2018 he was the scientific coordinator of 25 doctoral studies at the Doctoral School of Chemistry, Life Sciences and Earth at Alexandru Ioan Cuza University of Iași, Faculty of Geography and Geology, Department of Geography. At the same time, he was a mentor for 33 doctoral committees, a member in 25 committees for granting the title of doctor and a member in 1 committee for granting the honoris causa degree. He was also part of 2 postdoctoral international committees for doctors in Cameroon and Côte d'Ivoire and a coordinator for 8 international scholars from Senegal, Côte d'Ivoire, Algeria, Tunisia and Romania. In addition, he was a board member of several councils of research institutions in Romania, from which is worth mentioning: Interdisciplinary Research Department – Feald Science, Alexandru Ioan Cuza University of Iași; CERNESIM - Center for Studies in Environmental Science for the North - East Region, Alexandru Ioan Cuza University of Iasi, etc. Between 2006 and 2018, he was the Director of the Geoarchaeology Laboratory and between 2016 and 2018 he also held the position of Senior Researcher at CERNESIM - Center for Studies in Environmental Science for the North - East Region at Alexandru Ioan Cuza University of Iași. Starting with 2017 he became Director of the Doctoral School of Geosciences, Alexandru Ioan Cuza University of Iași, Faculty of Geography and Geology.

As far as the passion for scientific expeditions is concerned, between 1994 and 2014, the adventurer Gheorghe Romanescu, has organized 14 scientific expeditions travelling on 5 continents: 1. Scientific Expedition in the Atlantic Ocean (September - October 1994) in collaboration with Southampton Institute of Oceanography, under the guidance of Professor M. Collins; 2. Scientific expedition to the southern sector of Baikal Lake - "Baikal 2001" (September – October, 2001); 3. Tierra del Fuego (Patagonia) Expedition - "Ushuaia 2002" (February 2002) (Figure 1.b); 4. Lapland Expedition (March 2005); 5. Scientific Expedition to Labrador (June-July 2005); 6. India-Nepal Scientific Expedition (August-September 2005); 7. Expedition to Australia's Great Deserts (July-August 2006) (Figure 1.d); 8. Scientific Expedition to the Pampas of Argentina and Paraná Delta - South America (February 2008); 9. Atacama Desert Scientific Expedition (March 2008); 10. Scientific Expedition to the Andes (Altiplano) (March 2008) (Figure 1.a); 11. Scientific Expedition to Amazonia (March 2008); 12. Scientific Expedition to Alaska (May-June 2008); 13. Expedition to the Sahara Desert (August 2008); 14. Scientific Expedition to Kamchatka, Russia (June-July 2014) (Figure 1.c). In addition to its stunning stories about the *pink dolphins* in the Amazon, the snowy peaks of the Andes or the depth of Baikal Lake, which he often shared with his students during courses and seminars, the adventurer Gheorghe Romanescu left a legacy and an impressive collection of photographs (> 100,000 pictures) from all over the world.

As a person, Gheorghe Romanescu was much more than the sum of all the scientific and academic achievements gained during his life and everyone who had the privilege and the joy of working with him can testify this. It is difficult to describe the magnitude of its influence on the geographic community around the world, but the terms "spider flow" and "loesscape" have been frequently cited lately. He was a great mentor not only for the 25 PhD students he trained, but also for a wide range of students, master students, academic assistants, researchers and in the past few years to anyone around the world who sought his help and advice. Those who met him, either in the university's amphitheatres where he lectured or through his expeditions, were immediately impressed not only by his contagious enthusiasm for any problem to be solved, but also by his vision, combined with force and determination to fulfil his duty as a researcher. Since he passed away, many colleagues have expressed their gratitude, admiration and respect for him, acknowledging the impact he had on their lives, even if some of them have met him only occasionally. They all mentioned it was a privilege to know and work with such a geographic personality. It is not just about his impressive collection of scientific works, easily accessible and shared with others as an inheritance for future generations, but also about the memory of Gheorghe Romanescu as a free spirit. If it is difficult for us, as a scientific community, to imagine that he is no longer around to discuss a wide range of geographic issues, but even harder for his family to whom, through this manuscript, we express our sincerest condolences.

The death of Professor Gheorghe Romanescu is the sad loss of an astonishing individual, whose contribution to Earth sciences is immeasurable. His material and spiritual legacy will remain in the collective memory of the international academic and scientific environment as a prestigious didactician, explorer and exceptional geographer. The tribute to water memory through its specialized work in the field of hydrology, limnology, oceanography and delta and coastal geomorphology, will for a long time inspire new generations of geographers. On behalf of the *alma mater iassiensis* and the Geobalcanica community, the authors dedicate this short article to the family and friends of the great geographer of the waters!

ACTA GEOBALCANICA
5-2, 2019, pp. 47-55

# THE POTENTIALITY OF THE "DAPHNE" RAIN ENHANCEMENT PROGRAM IN THESSALY, GREECE

DOI: *https://doi.org/10.18509/AGB.2019.07*
UDC: *551.509.32:004.455]:551.584(495.3)*

**Theodore S. Karacostas**

*Department of Meteorology and Climatology, School of Geology, Faculty of Sciences, Aristotle University of Thessaloniki, Thessaloniki, Greece*

corresponding author: karac@geo.auth.gr

submitted: *04.04.2018*
accepted: *15.06.2018*
published: *18.01.2019*

**Abstract**
The developed Conceptual Model "DAPHNE" is presented. The model "DAPHNE" aims at tackling the problem of drought in the most vital agricultural area of Greece, Thessaly, by means of Weather Modification. It is developed through all the necessary scientific tools to support the potentiality and applicability of a well-designed precipitation enhancement program and to assess thoroughly the impact of its implementation on the environment. Its development relied upon: (i) the 10-year period 2001-2010 surface and upper air meteorological measurements, (ii) the use of the state-of-the-science WRF numerical model with sophisticated microphysical parameterizations, (iii) the adaptation of the 3D cloud model for performing simulations of cloud seeding experiments, (iv) the radar information from a C-band (5-cm) weather radar, through the "TITAN" (Thunderstorm Identification, Tracking, Analysis, and Nowcasting) algorithm and (v) the conduction of instrumented aircraft flights for in-situ measurements and carrying out actual aircraft cloud seeding experiments on suitably chosen appropriate clouds over Thessaly area. Moreover, sampling of precipitated water and consequent soil is performed to investigate the impact of the seeding material on the environment. It is believed, that all these state-of-art tools and aircraft observations have been combined to create the necessary fundamental principles for the development of the "DAPHNE" Conceptual Model that will potentially define the feasibility and applicability of a future rain enhancement program in Thessaly. The developed conceptual model potentially defines -if, when, where and how- a precipitation enhancement program would be applicable over the examined area. It sets the spatial, temporal and meteorological conditions that must be met, so that cloud seeding of appropriate cloud types will be feasible, aiming in precipitation enhancement and mitigation of drought in the major area of Thessaly, Greece.

Key words: "Daphne"; conceptual model; weather modification; rain enhancement; Thessaly-Greece.

## INTRODUCTION

The effects of climate change and the continued increase in water needs, for both urban and agricultural use, have largely exhausted water supplies; therefore, an effort must be taken in order to find new ways to augment them. Weather modification has a rather unique status among water resource issues, dealing with cloud seeding that helps clouds more efficiently produce precipitation in the form of rain or snow, or reduce hailstone size in favor of raindrops. The most beneficial and ambitious methodology is that of the precipitation enhancement. In recent years, the development of new sophisticated atmospheric models, in conjunction with modern instruments for recording and measuring atmospheric and cloud physics data have increased the interest in weather modification, and particularly for precipitation enhancement projects [1].

The objective on this study is to present the project DAPHNE, which is focused in the development of necessary scientific tools, to support the potentiality and applicability of a well-designed precipitation enhancement program, by applying state-of-the-science modeling tools, performing measurement campaigns and cloud seeding experiments on suitably chosen appropriate clouds, and investigating the impact of its implementation on the environment. It is applied over the Thessaly plain, which is known as the most vital agricultural area in Greece, where the water needs for urban and agricultural use have been largely exhausted. Hence, weather and climate, through weather modification is called to play a very important role in nation's socio-economic status. Figure 1 partially depicts, in a schematic diagram, the concept and thyme of the project DAPHNE.

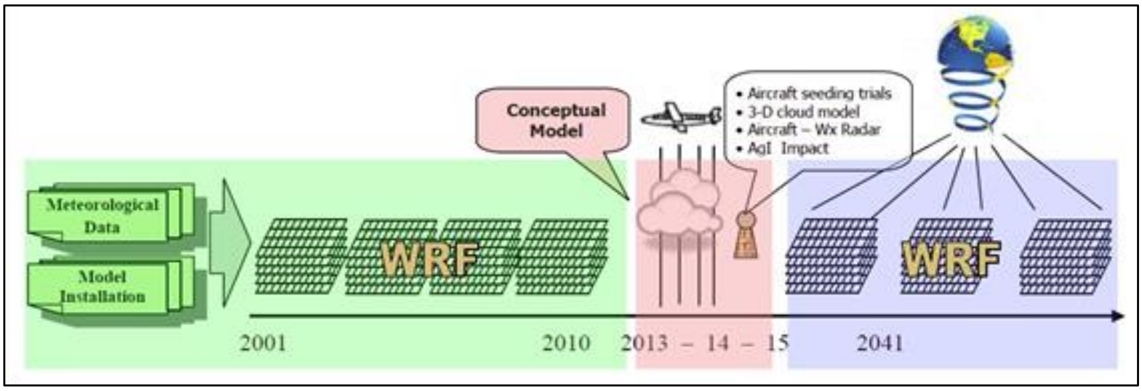



**Figure 1.** The schematic diagram of the project DAPHNE.

## DATA AND METHODOLOGY

The database of the project DAPHNE includes: a) surface observations from the available manual and automatic meteorological stations of the greater area of Thessaly, b) radiosonde data from the synoptic meteorological station at the airport of Thessaloniki, c) weather radar images received and analyzed from the C-band (5-cm) weather radar, d) specially equipped aircraft measurements (e.g. air temperature, humidity, liquid water content, height, etc.), e) meteorological data (air temperature, precipitation, humidity, atmospheric pressure and wind) from Larissa weather station for a period of 60 years (1950-2010), f) weather charts of daily analyses from ECMWF at 500 hPa at 1200 UTC, for the 10-year period 2001-2010, g) gridded analyses from the ECMWF/IFS system for the period 2001-2010, h) gridded projections of RegCM3 regional climate model (25km x 25km) carried out during ENSEMBLES project under the IPCC scenario A1B, for the period 2041-2050, i) chemical samples of soil and water from the seeded and unseeded areas, for environmental impact assessment studies.

The project DAPHNE integrates all contemporary components in order to have the most comprehensive state-of-the-science results. These components include the use of the state-of-the-art Weather Research and Forecasting (WRF) numerical model at very high resolution (1km x 1km), considering the different types of hydrometeors through sophisticated microphysical parameterizations, the adaptation and redevelopment of a 3D cloud model for performing simulations of seeding material dispersion and high-performance seeding aircraft.

It is the first time that these state-of-the-science tools and aircraft observations are combined in order to create the fundamental principles for the development of the Conceptual Model that define the feasibility potential of a rain enhancement program in Thessaly. The conceptual model will define if, when, where and how a precipitation enhancement program would be applicable over the examined area. It sets the spatial, temporal and meteorological conditions that must be met, so as cloud seeding of appropriate cloud types will be feasible, aiming in precipitation enhancement and mitigation of drought in the area of Thessaly.

## TECHNOLOGICAL INSTRUMENTATION AND RESULTS

The non-hydrostatic WRF model with the Advanced Research (WRF-ARW) dynamic solver [2, 3] is utilized in the framework of project DAPHNE. The installation is performed on a parallel computing platform (cluster) and all the necessary pre and post-processing modules have been created, taking into consideration the special characteristics of the project.

The model is integrated in three domains, using 2-way telescoping nesting, which cover Europe, the Mediterranean Sea and northern Africa (d01), the wider area of Greece (d02) and central Greece – Thessaly region (d03), at horizontal grid-spacings of 15km, 5km and 1km, respectively (Fig. 2), utilizing the staggered Arakawa C grid. Special care has been taken, regarding the spatial definition of the innermost domain, which focus in the area of interest (Thessaly) due to the surrounding complex topography. Fine-resolution (30''x30'' and 3''x3'') data are available for the definition of topography and land-use. The initial and boundary conditions of the coarsest domain can be optionally provided by: a) the NCEP/GFS analyses and forecasts (operationally), b) the ECMWF/IFS analyses and c) the RegCM3 regional climate model. ECMWF operational analyses at 6-hourly intervals (0.25° x 0.25° lat.-long.) and NCEP/GFS analyses and forecasts (operationally) can be imported as initial and boundary conditions of the coarse domain.

The sea-surface temperatures (SSTs) can be provided daily by NCEP (National Centers for Environmental Prediction) at a horizontal resolution of 1/12°x1/12°, ECMWF analyses or by the RegCM3 fields. The NCEP SSTs are produced on a daily basis through the assimilation of the most recent 24-hours sea-surface observations and satellite SST measurements. In the vertical, all nests employ 39 sigma levels (up to 50 hPa) with increased resolution in the boundary layer. Microphysical processes are represented by WSM6 scheme, sub-grid scale convection by Kain-Fritsch scheme, longwave and shortwave radiation by RRTMG scheme, surface layer by Monin-Obukhov (MM5), boundary layer by Yonsei University and soil physics by NOAH Unified model.

The Goddard scheme, the Betts-Miller-Janjic scheme, the RRTMG, the Monin-Obukhov (Eta), the Mellor-Yamada-Janjic and the NOAH Unified model are employed in all nests to represent microphysics, sub-grid scale convection, longwave/shortwave radiation, surface layer, boundary layer and soil physics, respectively. The Goddard microphysical scheme [4 and 5] contains separate variables for the calculation of cloud water, rain water, ice, snow and graupel (or hail).

The WRF model is used to produce very high spatiotemporal resolution simulations of the atmospheric conditions in the area of interest and provide the forcing fields to the 3D Cloud model.

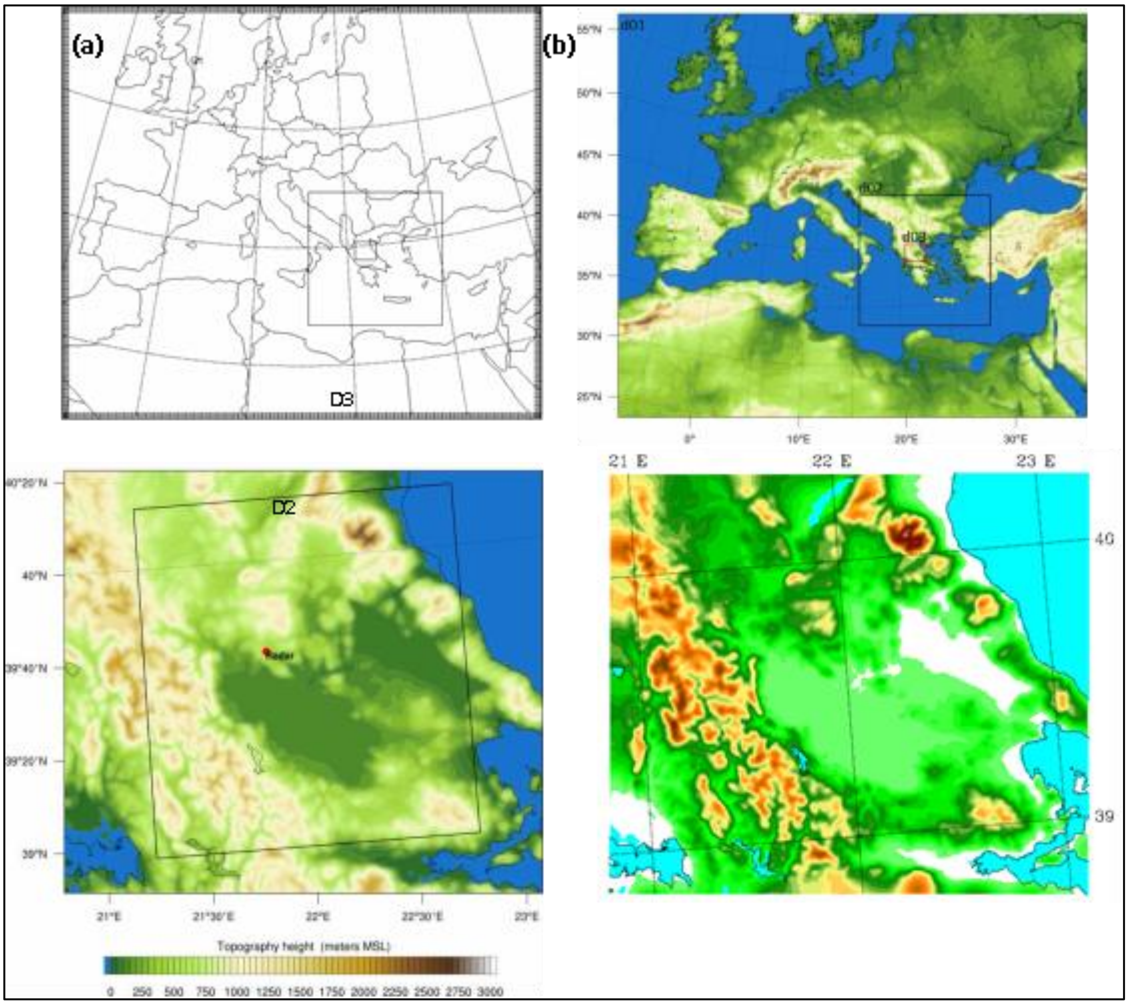



**Figure 2.** The three nests used by WRF-ARW in the project DAPHNE (a and b) and the examined area and topography of the inner domain (D03) (c and d).

The 3D cloud model [6] is a three-dimensional, non-hydrostatic, time-dependent, compressible system, which was initially developed by Telenta and Aleksic [7] and modified by Spiridonov and Curic [8]. It is based on the Klemp and Wilhelmson [9], the bulk cloud microphysics scheme from Lin et al. [10] that takes into account 6 water variables (water vapor, cloud droplets, ice crystals, rain, snow and graupel) and Orville and Kopp [11] thermodynamics. The bulk microphysical parameterization uses a double- moment scheme for all species. The activation of the seeding material, where the AgI has been adopted, is parameterized by the three nucleation mechanisms based on Hsie [12] and Kopp [13] and the calculation of agent dispersion is done using an additional conservation equation. The dispersion of the agent takes place on a sub-grid scale, while the advection and diffusion are represented by individual puffs spreading in time according to the turbulent diffusion coefficients proposed by Georgopoulos and Seinfeld [14]. The equivalent radar reflectivity factors for hail and rain are computed according the equations given by Smith et al. [15] and the empirical equation for snow by Sekhon and Srivastava [16]. More detail information about the model, initial and boundary conditions, numerical technique and initialization could be found in Telenta and Aleksic [7], Spiridonov and Curic [6], Barth et al. [17] and Spiridonov et al. [18].

The 3D cloud model is applied to representative cases of past, present and future-projected weather conditions, using the actual radiosonde data of the nearest upper air station (Thessaloniki synoptic station) and the output of the WRF simulations. The cloud model sensitivity to the different sources of input data (radiosonde, WRF) is assessed for the present-weather cases. Initial impulse for convection is an ellipsoidal warm bubble with maximum temperature perturbation in the bubble center. The model domain has dimensions of 60x60x20km3, while the spatial grid resolution is 500x500x250m and the temporal integration resolution is 5s and 10s, plus a smaller one of 1s and 2s, for solving sound waves.

Storm characteristics are obtained and identified from weather radar reflectivity images received and analyzed from the C-band (5-cm) weather radar, being located at Liopraso area (39.674oN, 21.837oE; Fig. 2c), within the area of interest. The interfaced cell tracker TITAN (Thunderstorm Identification, Tracking, Analysis, and Nowcasting) (Dixon and Wiener, 1993) has been used to retrieve convective storm tracks and characteristics from radar reflectivity measurements that roughly have 750x750m spatial and 3.5min temporal resolution. The storm characteristics include: initiation time (UTC hour), duration (minutes), direction ($^{o}$), speed (km/hr), volume (km$^{3}$), area and precipitation area (km$^{2}$), rain rate (mm/hr), maximum reflectivity (dBz), cloud top (km) and many more parameters.

The prevailing synoptic conditions in the greater area of central Greece, during the 10-year period 2001-2010, have been classified, one by one day, according to the general circulation pattern of the middle troposphere. This information was retrieved mainly by daily analyses of ECMWF at 500 hPa at 1200 UTC. The classification is based on the methodology initially introduced by Karacostas et al [19], followed up by Karacostas [20] and Karacostas et al [21]. Adopting the same methodology and procedure, the mid-tropospheric synoptic circulation patterns, projected by the RegCM3 regional climate model -under the IPCC scenario A1B- during the period 2041-2050, have also been classified. The resulted daily synoptic circulation patterns have been statistically analyzed and compared, in order to investigate the prevailing near-present and future synoptic conditions. To meet the project objectives, representative cases of the near-present and future synoptic conditions were selected and analyzed for the model simulations. Results of such kind of studies have been presented by Karacostas et al [22].

The core experimental work of the project DAPHNE took place from the 1$^{st}$ of March to the 31$^{st}$ of October 2014, with emphasis on the first 45 days and the last 31, due to the lack of existed previous data information and with the objective to accomplish a complete data set. During these measurement campaigns, the following procedures took place, according to our own operational meteorological forecasts. Appropriate surface and upper air meteorological measurements were performed. Weather radar images were received and analyzed from the C-band (5-cm) weather radar being located at Liopraso area, within the area of interest. Aircraft flights were conducted, by specially instrumented and equipped aircrafts, with specialized on the subject pilots, in order to perform in-situ appropriate measurements. At the same time, and after meeting pre-specified criteria, cloud seeding experiments were carried out on selected clouds. Chemical samplings of soil and water from the seeded area were conducted, and impact study analyses were performed. Sampling from the surrounding background areas was also performed for comparison purposes.

It is believed and also proven that the aforementioned field experiments and measurement campaigns, coupled with numerical model simulations and proper seeding technologies and procedures, very well support the main objective of the project DAPHNE. Figure 3 depicts only some of the aforementioned storm measurements, synthesized together with the 10-year data information, for the south-west (SW) upper-air synoptic circulation type. Similar analyses and presentations have been conducted for each one of the upper-air synoptic circulation types encountered throughout the DAPHNE project.

An investigation concerning the impact of the seeding material on the environment has been conducted, by sampling of precipitated water and consequent soil, immediately after the cloud seeding performance. It is known that the Silver Iodide (AgI) determination in complicated samples like soils containing important amounts of organic matter, is not an easy task, which becomes more difficult, taking into account the extremely low concentrations of the dispersed amount of AgI in the total precipitation and furthermore in the large mass of ground soil. Hence, soil samples were collected according to the standard sampling procedure from two types of areas: (a) from sampling sites inside the targeted area, where the cloud seeding project is applied and (b) from sampling sites outside the targeted area, where no cloud seeding has been applied ever, and analyzed for their silver concentrations. In addition, precipitated water samples after seeding procedures were also collected and analyzed in an analogous manner, for the same purpose and objectives. Although total silver (Ag) was measurable in almost all soil samples, the concentrations were found in average levels. On the other hand, no silver iodide (AgI) residues were detected. Regarding surface water samples, no detectable silver (Ag) concentration was found [23].

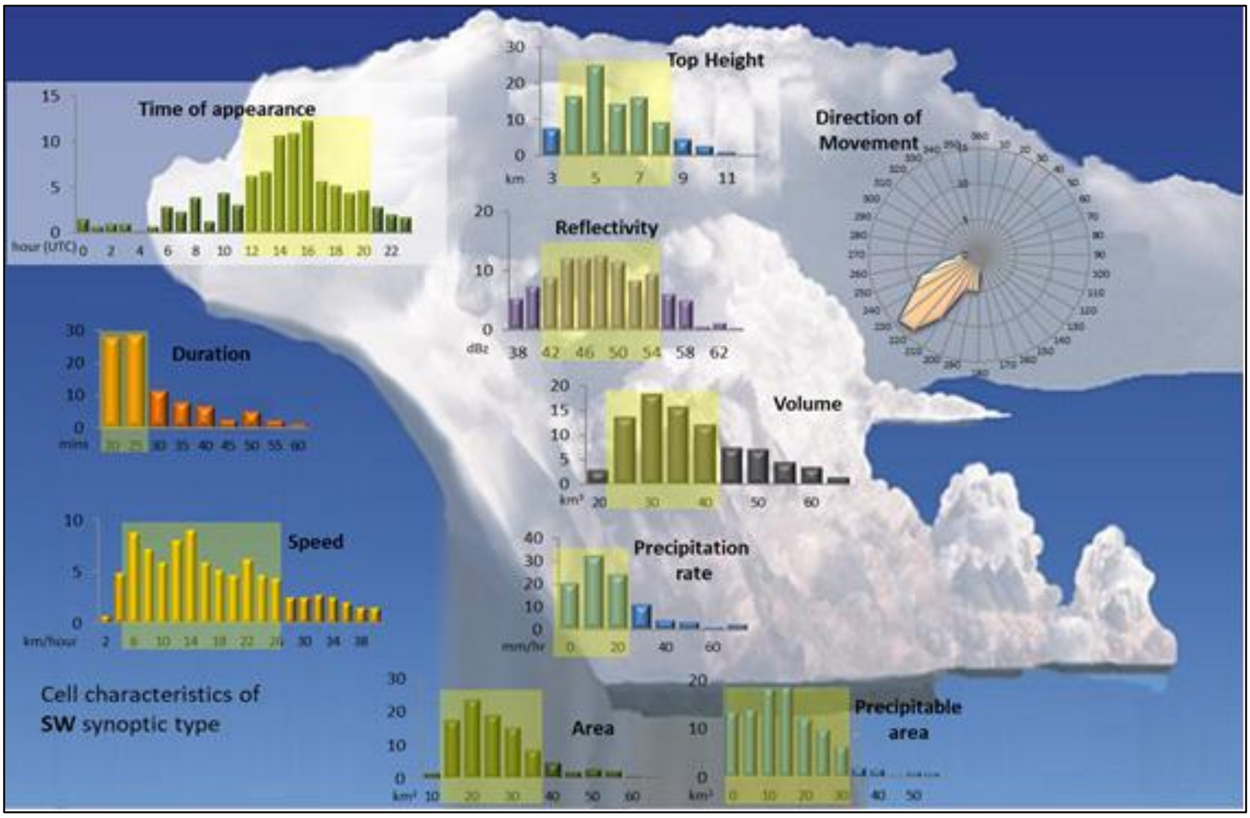



**Figure 3**. Storm characteristics, synthesized from the 10-year data information, for the south-west (SW) upper-air synoptic circulation type, for the project DAPHNE.

Furthermore, the use of the state-of-the-science numerical weather prediction model (WRF-ARW ver3.5.1), which was simulated and operationally predicted the characteristics of convective activity, showed to be in good agreement with observations, enhancing thus the scientific knowledge [24]. Sensitivity tests, which were also performed by Tegoulias et al [25], exhibited good agreement between actual and simulated values. Moreover, the adoption of the 3D cloud model, acted as a valuable tool at investigating responses on cloud dynamical and microphysical features, making possible to measure and test precipitation enhancement against different seeding methods, rates and locations [26 and 27].

## THE "DAPHNE" RAIN ENHANCEMENT CONCEPTUAL MODEL

The main objective of the DAPHNE project was to integrate, in a state-of-the-art manner, all the presented contemporary scientific components, in order to have the most comprehensive state-of-the-science results, in the form of the "DAPHNE" rain enhancement Conceptual Model, emerging throughout the analyzed and studied data information. Some of these components are: the use of the state-of-the-art WRF numerical model with sophisticated microphysical parameterizations, the adaptation of the 3D cloud model for performing simulations of cloud seeding experiments, the radar information from the C-band (5-cm) weather radar through the TITAN algorithm, the conduction of instrumented aircraft flights for in-situ measurements by carrying out actual cloud seeding experiments and last but not least, to investigate the impact of the seeding material on the environment. It is strongly believed, that it is for the first time that all these state-of-the-science tools and aircraft observations are combined, in order to create the necessary fundamental principles for the development of the conceptual model that would actually define the feasibility potential and applicability of a rain enhancement program in Thessaly. Hence, the "DAPHNE" rain enhancement Conceptual Model specifically defines ***-if, when, where and how-*** a precipitation enhancement program would be applicable over the examined area. It sets the spatial and temporal meteorological conditions that must be met, so that, cloud seeding of appropriate cloud types will be feasible, aiming in precipitation enhancement and mitigation of drought in the area of Thessaly.

The schematic diagram of the "DAPHNE" rain enhancement Conceptual Model, indicating the potentiality and applicability of a rain enhancement program in Thessaly, is fully demonstrated in Figure 4. The incorporated arithmetic "typical" values correspond to cloud characteristics with reflectivities greater than 35 dBz.

Combining the results from the analyses into discrete categories and factors, the hydro-climatic factor suggested that a rain enhancement program should be applied over the examined area during the period of increased water needs and when soil moisture deficit becomes evident. Relying upon the characteristics depicted on Figure 4, this period seems to be oriented from March to October. Actually, the period from 10 of March to 20 of October is proposed as the feasible period for conducting a rain enhancement program in the area of Thessaly, Greece.

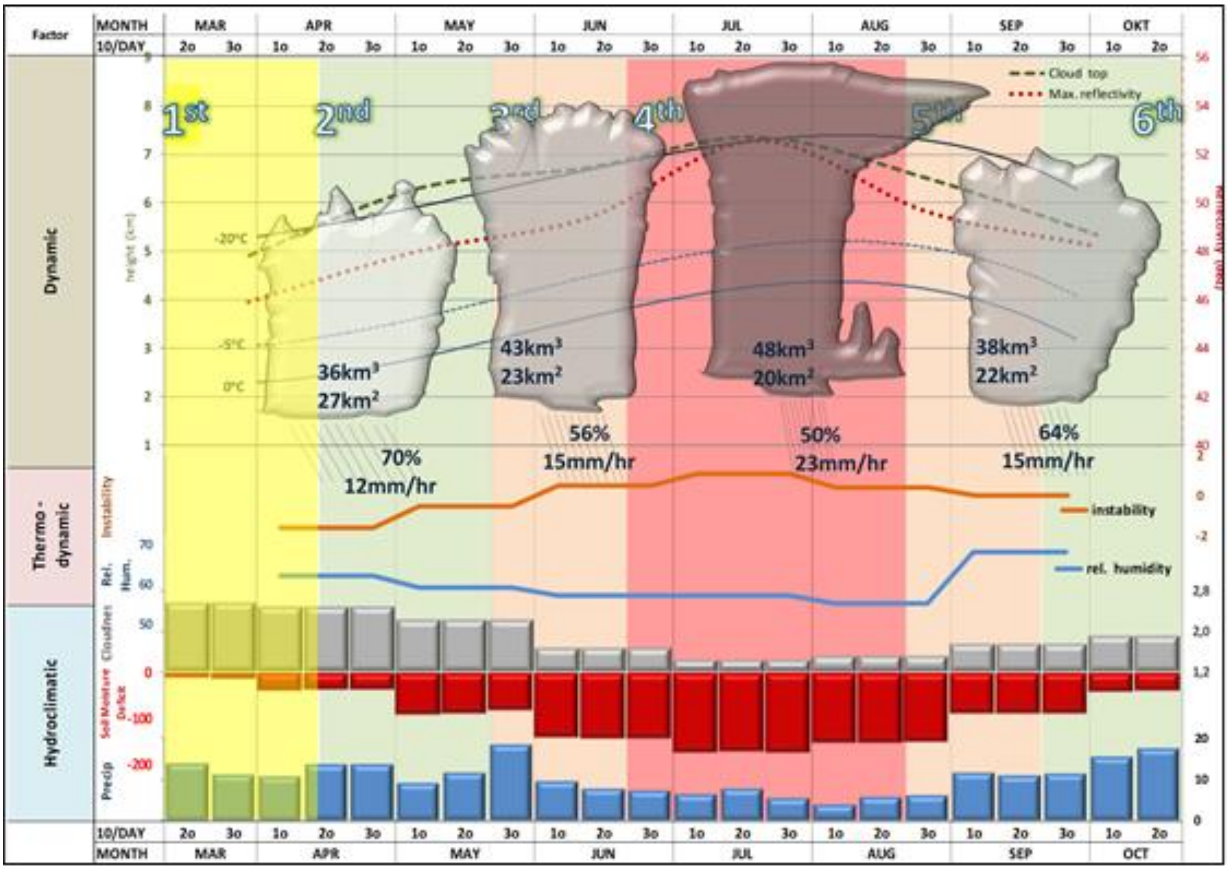



**Figure 4.** A schematic diagram of the "DAPHNE" rain enhancement Conceptual Model in the area of Thessaly, Greece.

The synoptic factor, expressed mainly by the magnitude of the frontal systems that pass over the area and the associated other synoptic features, suggests that the application of a program over well-organized weather systems would have little impact on precipitation enhancement, since such systems are capable by themselves of producing large and widespread amounts of precipitation. Conversely, weather systems during the so called warm period (March to October, for the examined area) exhibit convective and dynamical characteristics, and therefore, these systems are amenable for cloud seeding.

The thermodynamic factor, denoting the atmospheric instability, is maximized during the warm period, reaching its maximum values during July (Figure 4). Storms developing under conditions of high atmospheric instability are also not eligible to conduct cloud seeding, since such storms can effectively produce precipitation and sometimes even damaging hail. Of course, not all weather systems are dynamically strong enough and hence, atmospheric instability is not always too high to prevent the application of a rain enhancement program.

According to the dynamic and microphysical factors, the clouds developing over the area meet all the necessary conditions related to upward motion and horizontal and vertical extent, appropriate cloud base and cloud top temperatures and reflectivity values, in order to perform a rain enhancement program. The primary reason for cell characteristics differentiations is the time of appearance within the period of study and secondly the synoptic and dynamic conditions for the cells' development. Therefore, based upon the aforementioned factors and characteristics, the "DAPHNE" rain enhancement Conceptual Model could be differentiated in time into the following six (6) sub-periods, providing thus the opportunity to introduce and apply altered concepts on physical hypotheses and even different seeding rates:

1$^{st}$ sub-period: 10 March - 10 April
2$^{nd}$ sub-period: 11 April - 25 May
3$^{rd}$ sub-period: 26 May - 25 June
4$^{th}$ sub-period: 26 June - 25 August
5$^{th}$ sub-period: 26 August - 25 September
6$^{th}$ sub-period: 26 September - 20 October

During the 1$^{st}$ period, cells tend to develop due to synoptic conditions, mainly within frontal systems as embedded convective areas. These cells are almost evenly distributed day and night. Part of the 1$^{st}$ period and mainly during the 2$^{nd}$ period, the cells are almost evenly distributed during the day and usually extend from 1.3 km up to 6 km. Mean volume of these cells is about 36 km$^3$, mean area 27 km$^2$ and precipitation rate about 12mm/hr, covering almost the 70% of their total precipitation area. During the 3$^d$ period, convective cells appear mainly due to atmospheric instability during the warm hours of the day and secondly from the weather systems. They indicate greater vertical extent, compared to the previous ones, reaching heights up to 8 km, resulting in bigger cloud volume: 43 km$^3$, but less area: 23 km$^2$ and even less precipitation area (56%), but with higher precipitation rate: 15mm/hr. In the 4$^{th}$ period, which is the heart of the warm season, isolated convective cells develop mostly as a result of atmospheric instability, exhibiting the strongest characteristics, with tops up to 9 km and sometimes even more, volume of 48 km$^3$, area of 20 km$^2$, and even less precipitation area 50 km$^2$, with the highest encountered precipitation rate of 23mm/hr. In the 5$^{th}$ and 6$^{th}$ periods, the convective cells gradually lose some of their strength characteristics, as atmospheric instability decreases with time period. Their characteristics lie among those encountered between the 3$^d$ and the 2$^{nd}$ period, as they are influenced by both, atmospheric instability and frontal systems. Hence, they reach heights up to about 7 km, with cloud volume 38 km$^3$ and area of 22 km$^2$. The encountered precipitation rate drops gradually down to 15mm/hr, covering at the most a precipitation area of 64% of the total one.

## SYMMARY AND CONCLUSIONS

The implementation scope of the project DAPHNE is to tackle the problem of drought in Thessaly by the scientific means of weather modification. The Thessaly plain is known to be a vital agricultural area in Greece, and thus the weather and climate play a very important role in its socio-economic status. Anthropogenic climate change is expected to further deteriorate the problem of drought and water shortage, posing a serious threat in human and agricultural activities. It appears, thus, a necessity to investigate the potential impact of present weather and climate change on drought, in order to suggest effective ways of tackling the already existed -and for sure- future problem.

The synthesis of all the available data that was performed during the period of the project DAPHNE has resulted in the formation of the conceptual model. According to the DAPHNE Conceptual Model, a precipitation enhancement program could potentially be applied over the area of Thessaly-Greece from the 10$^{th}$ of March to the 20$^{th}$ of October.

Six consecutive time periods appear to consist the yearly operational period, demonstrating thus the necessity for similar, different, or at least modified seeding hypothesis, according to the storm's synoptic, dynamic, thermodynamic and microphysical characteristics.

One of the main and proven concluding remarks is that the cells' characteristics are being primarily altered in time, seasonally and mainly through the synoptic, dynamic, thermodynamic and microphysical processes of cells' developments. Thus, the feasible application period has been divided into six (6) sub-periods, due to changes in cloud characteristics, as these are depicted within the DAPHNE Conceptual Model (Figure 4). The most favorable sub-periods for application are: 2$^{nd}$, 3$^{rd}$ 5$^{th}$ and 6$^{th}$ sub-periods. The 1$^{st}$, 2$^{nd}$ and 6$^{th}$ sub-periods are mostly dominated by the synoptic factor, the 4$^{th}$ sub-period by the thermodynamic and microphysical factors, while all the aforementioned factors affect the 2nd, 3rd and 5th sub-periods, as well. It is intuitively true that all the aforementioned are expected to be fully develop and emphasize the strong interaction between cloud dynamics and microphysics, especially in small scale processes, which influence seeding agent transport and diffusion within the storm's complex environment. Seeding effects are strongly depended upon the seeding strategy, relying on the exact seeding time, the right placement of the seeding agent and the appropriate seeding rate.

The analyses performed within the project DAPHNE constitute the scientific part which is the most vital component before conducting a weather modification program. A techno-economical study is of paramount importance and necessary, in order to evaluate all costs associated with the application of the program, before the decision to proceed with an operational weather modification program is made.

***Acknowledgments*** This research work of DAPHNE project is co-funded by the European Union (European Regional Development Fund) and Greek National Funds, through the action "COOPERATION 2011: Partnerships of Production and Research Institutions in Focused Research and Technology Sectors" in the framework of the operational programme "Competitiveness and Entrepreneurship" and Regions in Transition (OPC II, NSRF 2007-2013).

## REFERENCES

[1] Silverman, B.A. A Critical Assessment of Hygroscopic Seeding of Convective Clouds for Rainfall Enhancement. *Bulletin of the American Meteorological Society*, 1219-1230, 2003.

[2] Skamarock, W.C., Klemp, J.B., Dudhia, J., Gill, D.O., Barker, D.M., Duda, M.G., Huang, X-Y., Wang, W., Powers, J.G. *A description of the Advanced Research WRF Version 3*. NCAR/TN-475, 2008.

[3] Wang, W., Bruyère, C., Duda, M., Dudhia, J., Gill, D., Lin, H.-C., Michalakes, J., Rizvi, S., Zhang, X., Beezley, J., Coen, J. and Mandel, J. *ARW Version 3 Modeling System User's Guide*. NCAR-MMM. 352 pp., 2010.

[4] Tao, W-K and Simpson, J. The Goddard cumulus ensemble model. Part I: Model description. *Terr. Atmos. Oceanic Sci.*, 4, 35–72, 1993.

[5] Tao, W-K., Simpson, J, Baker, D., Braun, S., Chou, M.-D., Ferrier, B., Johnson, D., Khain, A., Lang, S., Lynn, B., Shie, C.-L., Starr, D., Sui, C.-H., Wang, Y., and Wetzel, P. Microphysics, radiation and surface processes in the Goddard Cumulus Ensemble (GCE) model. *Meteor. and Atmos. Phys.*, 82, 97–137, 2003.

[6] Spiridonov, V., and Curic, M. A three-dimensional modeling studies of hailstorm seeding. *J. Weather. Modif.*, 38, 31–37, 2006.

[7] Telenta, B., and N. Aleksic. A three-dimensional simulation of the 17 June 1978 HIPLEX case with observed ice multiplication, *2nd International Cloud Modelling Workshop*, Toulouse, 8-12 August 1988. WMO/TD No. 268, 277-285, 1988.

[8] Spiridonov, V., and Curic, M. Application of a cloud model in simulation of atmospheric sulfate transport and redistribution. Part I. Model description. *Idojaras Quart*, 107, 2, 85-115, 2003.

[9] Klemp, J.B., Wilhelmson, R.B. The simulation of three-dimensional convective storm dynamics. *J. Atmos. Sci.*, 35, 1070–1096, 1978.

[10] Lin, Y-L., Rarley, R.D., Orville, H.D. Bulk parameterization of the snow field in a cloud model. *J. Appl. Meteorol., 22*, 1065–1092, 1983.

[11] Orville, H.D., Kopp, F.J. Numerical simulation of the history of a hailstorm. *J. Atmos Sci., 34*, 1596–1618, 1977.

[12] Hsie, E.Y., Farley, R.D., Orville, H.D. Numerical simulation of ice-phase convective cloud seeding. *J. Appl. Meteorol.*, 19, 950–977, 1980.

[13] Kopp, F.J. A simulation of Alberta cumulus. *J. Appl. Meteorol., 27*, 626–641, 1988.

[14] Georgopoulos, P.G., and Seinfeld, J.H. Mathematical modeling of turbulent reacting plumes – general theory and model formulation. *Atmos. Environ., 20*, 1791–1802, 1986.

[15] Smith, P.L., Myers, G.G., Orville, H.D. Radar reflectivity calculations on numerical cloud models using bulk parameterization of precipitation. *J. Appl. Meteor., 14*, 1156-1165, 1975.

[16] Sekhon, R.S., Srivastava, R.C. Snow size spectra and radar reflectivity. *J. Atmos. Sci., 27*, 299-307, 1970.

[17] Barth, M.C., Kim, S-W., Wang, C., Pickering, K. E., Ott, L. E., Stenchikov, G., Leriche, M., Cautenet, S., Pinty, J-P., Barthe, Ch., Mari, C., Helsdon, J. H., Farley, R. D., Fridlind, A. M., Ackerman, A. S., Spiridonov V., Telenta B.

Cloud-scale model intercomparison of chemical constituent transport in deep convection, *Atmos. Chem. Phys.*, *7*, 4709–4731, 2007.

[18] Spiridonov, V., Karacostas, T., Bampzelis, D., Pytharoulis, I. Numerical Simulation of Airborne Cloud Seeding over Greece, Using a Convective Cloud Model, *Asia-Pac. J. Atmos. Sci.*, 51(1), 1-17, 2015.

[19] Karacostas, T.S., Flocas, A.A., Flocas, H.A., Kakaliagou, O., Rizou, C. A study of the synoptic situations over the area of Eastern Mediterranean, *Proc., 1st Greek Conf. on Meteorology Climatology and Atmospheric Physics*, Thessaloniki-Greece, 469-477, 1992 *(in Greek).*

[20] Karacostas, T.S. The Greek National Hail Suppression Program: design, physical hypothesis and statistical evaluation. *In: Regional Seminar on Cloud Physics and weather modification. World Meteorological Organization*, WMP No. 42, WMO-TD No. 1227, 213 pp., 2003.

[21] Karacostas, T., Kartsios, S., Pytharoulis, I., Tegoulias, I., Bampzelis, D. Observations and modelling of the characteristics of convective activity related to a potential rain enhancement program in central Greece. *Atmospheric Research*. 208, 218-228. DOI: 10.1016/j.atmosres.2017.08.014, 2018.

[22] Karacostas, T., I., Pytharoulis, I., Tegoulias, S., Kartsios, D., Bampzelis and K., Tympanidis. Near-present and future precipitation characteristics in Thessaly area, being related to the upper-air synoptic circulation types. *14th International Conference on Meteorology, Climatology and Atmospheric Physics,* Alexandroupolis, Greece, 918-923, 2018.

[23] Anthemidis, A. N., G.A., Zachariadis, T., Karacostas, A.G., Zachariadis, J.A., Stratis. Trace Silver Determination in Surface Soil Matrices by Electrothermal Atomic Absorption Spectrometry. 9th Aegean Analytical Chemistry Days, Chios, 2014.

[24] Pytharoulis, I., Tegoulias, I., Kotsopoulos, S., Bampzelis, D., Karacostas, Th., Katragkou, E. Evaluation of the operational numerical weather predictions of theWaveForUs project. *12th International Conference of Meteorology, Climatology and Physics of the Atmosphere*, Heraklion, Greece, vol. 3, 96–101, 2014.

[25] Tegoulias, I., Pytharoulis, I., Bampzelis, D., Karacostas, T. Evaluation of Numerical Weather Predictions Performed in the context of the project DAPHNE, *Geophysical Research Abstracts*, Vol. 16, EGU2014-5637, EGU General Assembly, Wien, Austria, 2014.

[26] Bampzelis, D., Spiridonov, V., Kartsios, S., Pytharoulis, I., Tegoulias, I., Karacostas, T. Numerical Simulation of Airborne cloud Seeding for the DAPHNE Precipitation Enhancement Project in central Greece, *95th AMS Annual Meeting*, Phoenix, Arizona, USA, 2015.

[27] Spiridonov, V., Karacostas, T., Bampzelis, D., Pytharoulis, I. Numerical Simulation of Airborne Cloud Seeding over Greece Using a Convective Cloud Model. *Asia-Pac. J. Atmos. Sci.*, 51(1), 1-17, 2015.

ACTA GEOBALCANICA
5-2, 2019, pp. 57-73

# CHRONOLOGY OF THE URBAN EXPANSION OF SKOPJE

DOI: *https://doi.org/10.18509/AGB.2019.08*
UDC: *711.451:711.122(497.711)*

**Maja Lazarevska[1], Blagoja Markoski[2]**

*Ministry of Transport and Communications of the Republic of Macedonia*
*University of "Ss. Cyril and Methodius" - Skopje, Faculty of Natural Sciences and Mathematics, Institute of Geography, Macedonia*

corresponding author: majamateska@hotmail.com

submitted: *15.04.2018*
accepted: *25.06.2018*
published: *18.01.2019*

**Abstract**
The phenomenon of spatial expansion and sprawling of cities in one particular territory is a condition that has greatly influenced the contemporary city and society.
The topic of this study is the genesis and the matrix of the spatial development of Skopje and determining the cause-effect factors and results.
The main thesis of the study suggests necessity for introducing a program-spatial matrix/paradigm in the development, so as to regulate the spatial expansion of the urban web. The program-spatial matrix is associated with the segment of planning, or the introduction of the normative structure.
The work methodology is based on comparative analysis of the changes from a spatial-physical and a planning point of view. Due to the specifications of the region concerned, this study, in methodological sense, starts with providing documentary grounds, based on methods of collecting, documenting and analyzing the information found.
The conclusion of this study encourages the need for introducing a normative structure in the spatial development planning of cities in order to improve the spatial quality, the economic dynamics and the social cohesion.
The results of the study analyses ought to provide a clearer representation of the relations between the urban planning (spatial and general) and the space as well as the consequences of their implementation, or non-implementation.

Key words: The City of Skopje, Skopje Valley, spatial development, spatial expansion, urban development

## INTRODUCTION

The topic of this study is the City of Skopje, the conglomerate and the center of development, a pole with great influence in the region and the country itself, its geographical position in the region, or the spatial-physical context in the geographical surroundings, as a phenomenon with its own specific individual development. For better understanding of the issue, an analysis of the natural-geographic, socio-geographic and economic-geographic features of the space has been made.

The spatial and urban city planning has been observed as a special segment. Skopje is marked by more than hundred years of history of spatial planning. The spontaneous and non-regulated development (taking place until 1914) from 1914 is replaced by a process of urban planning of the city space. The planning documents are products of the social-political conditions that existed in that particular moment as well as of the position and the significance of Skopje in that particular territory.

From 1914 until today seven urban plans have been adopted, each of them covers the city integrally and define its development as such. The plans have different content and qualitative characteristics. They represent the contemporary surrounding and input at the moment, the atmosphere, the aspirations of the officials in charge and the actual relevant legislation, and their addition to the previous does not present continuity in the planning development related to the present condition.

In this study, different planning treatments are separately discussed in relation to the adopted plans, their decision on the borders of the urban-planning area as well as the city borders. The goal is to obtain more persistent analysis of the process of spatial and urban expansion of the City of Skopje.

## GEOGRAPHIC POSITION AND ADMINISTRATIVE ORGANIZATION

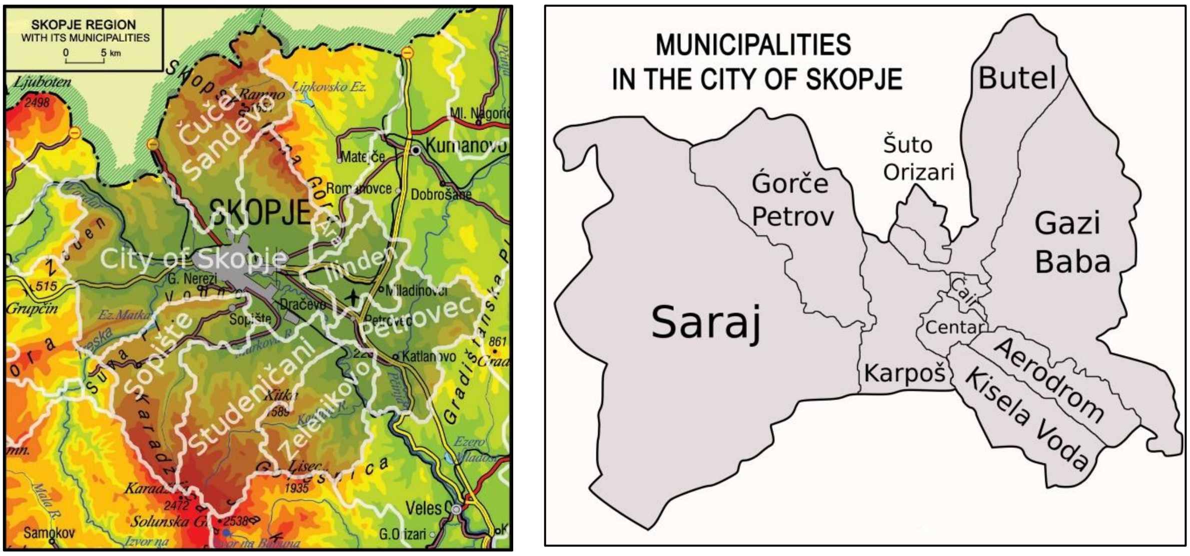
### Geographic position

The City of Skopje is placed in the Skopje Valley, in the northern part of the Republic of Macedonia at 41° 42'15"and 42°16'20" n.g.w (northern geographic width) and 21°09'40" and 21°49'15" e.g.w. (east geographic width) along Grinich. In the framework of its natural-geographic borders the valley covers an area of 1914 km$^2$ [21, 22, 23], or 7% of the Republic of Macedonia. The space is physically delimited with the mountain massif Karadzica and Goleshnica from south, Mountain Gradeshka from east to the Ovche Pole, the Kumanovo Valley and the Skopska Crna Gora massif from south, and the Zheden mountain from west seperates it from the Polog Valley. It is worth mentioning that the southern border of the Skopje Valley overlaps with the country border of Kosovo.


**Picture 1.** Geographic position of the Skopje Region in the Republic of Macedonia (by the autor)

### Administrative organization

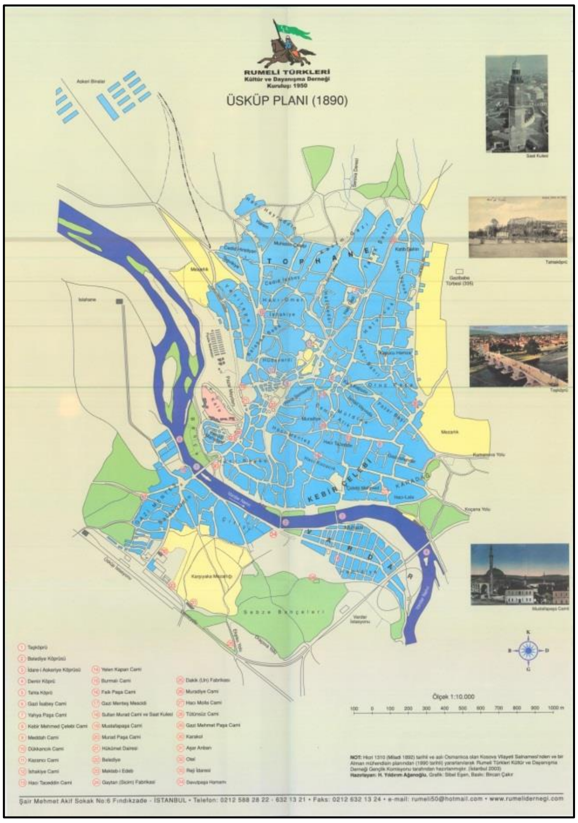
The territory of the Skopje Valley is administratively covered by the Skopje Region (NUTS – Nomenclature of Territorial Units for Statistics level 3) as one of the eighth non-administrative units-statistic regions that arouse from grouping municipalities from lower rank in as administrative units in the Republic of Macedonia. With the Law on Territorial Organization of the Local Self-government in the Republic of Macedonia [28] the territory of the planning region of Skopje has been organized in 17 units of the local self-governement – municipalities and the city of Skopje as a special unit of the local self-government. From the stated 17 municipalities, ten are seated in the City of Skopje (Aerodrom, Butel, Gazi Baba, Gjorche Petrov, Karposh, Kisela voda, Saraj, Centar, Chair and Shuto Orizari), and seven are municipalities outside Skopje, seated in a village (Arachinovo, Zelenikovo, Ilinden, Petrovec, Sopishte, Studenichani and Chucher Sandevo), along with the villages that pertain to them territorially.




**Picture 2.** Territorial organization of the region of Skopje [1,28]

## CHRONOLOGY OF THE URBAN EXPANSION OF SKOPJE

Several factors had a great impact on the evolutionary line of urban development of Skopje, such as - the social-political atmosphere, the dynamics of the administrative political changes, the role of Skopje as Capital and its significance regarding the surroundings, the legislative framework, the planning approach, the continuous structure as a built constructional fund and the conditions for implementing the planning solutions.

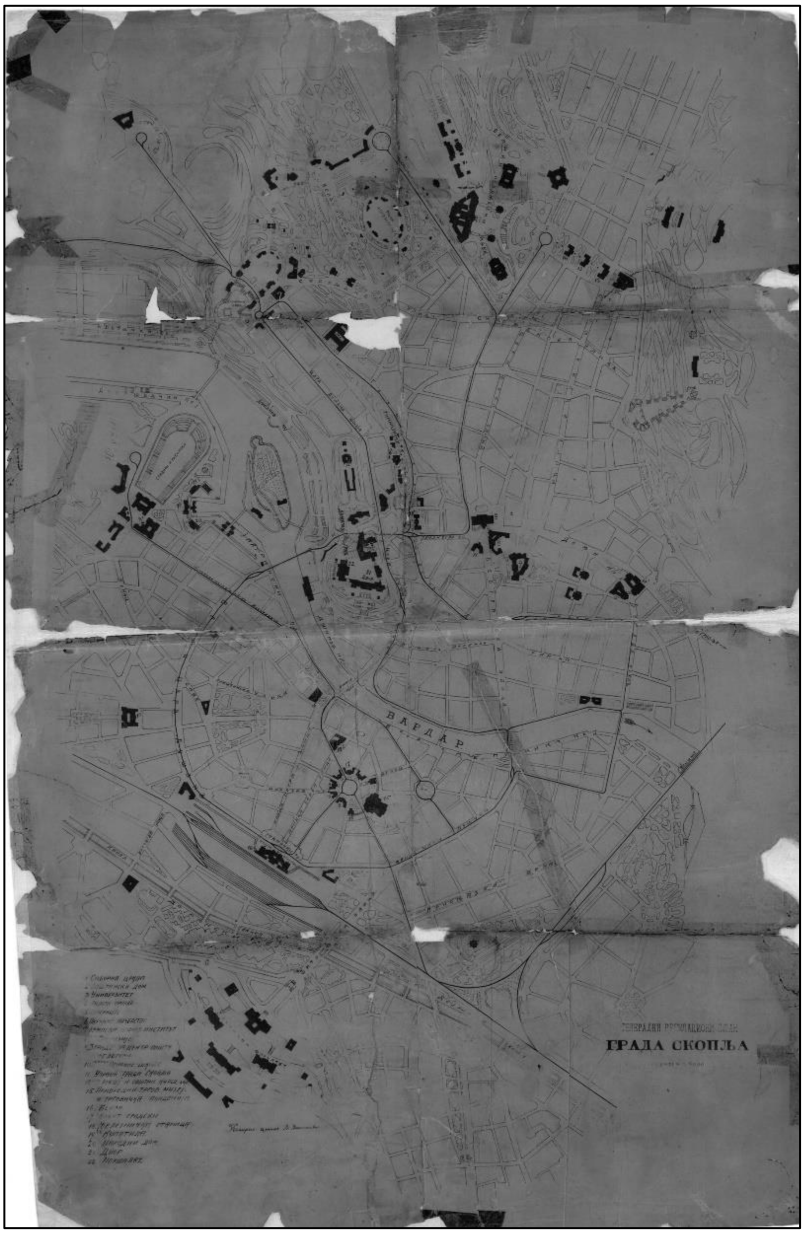



**Picture 3.** Reconstruction of the Skopje city structure from 1890 г. [31]

Note: The Hijri was prepared by the Youth Commission of the Association of Culture and Solidarity of the Rumeli Turks, who benefited from the Salmanesi of the Kosovo Vilayet, dated 1310 (Miladi 1890) and the original Ottoman, and a German engineer (Miladi 1890).(Istanbul 2003). Prepared by: H. Yildirim Aganoglu, Graphic: Sibel Esen, Printing: Bircan Cakir.

Generally, the urban development of Skopje can be seen through two periods: pre-planning period until

1914, and planning period from 1914 until today. In the pre-planning period, with a lack of space regulation for planning, Skopje was developing spontaneously and uncontrollably. The planning period started after the Balkan Wars, with freeing the city territory from the Ottoman Empire. The planning treatment of the city space has started since then [26].. This early planning period includes the first urban ideas for the City of Skopje. They are oriented towards de-Ottomanization, presenting ideas for transforming the existing city structure with elements from European cities.




**Picture 4.** Competition study: General Regulation Plan of the City of Skopje, 1914. Appendix with planned tram lines [4]

**Chronological preview of the urban plans**

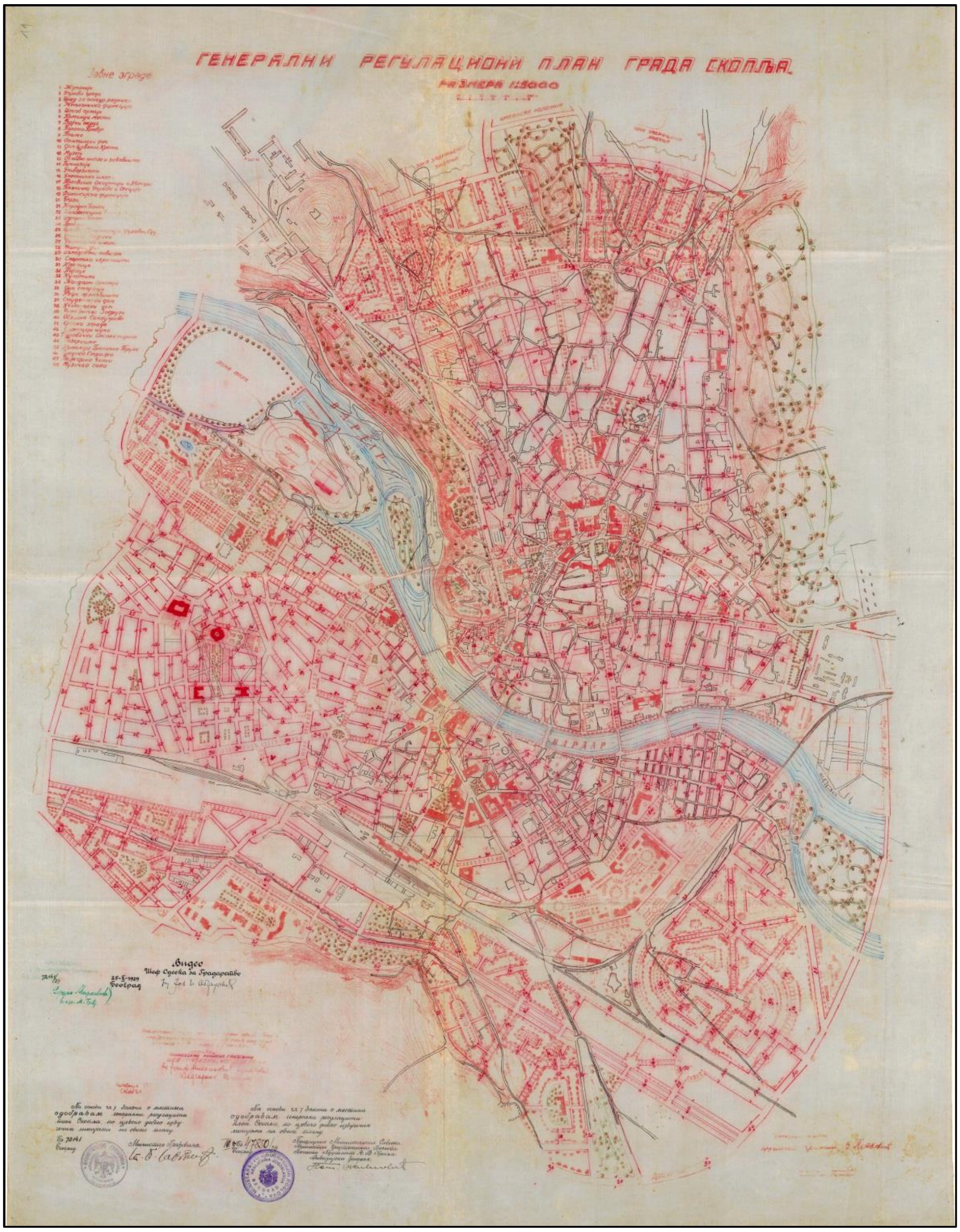
*The competition study/work of the architect Dimitrie T. Leko from 1914*

The competition work of the architect Dimitrie T. Leko is the first known planning document for the City of Skopje-the General Regulation Plan of the City of Skopje. The main concept of the study is the idea for a European image of the city, which is why the planning concept has radical visions for the urban development regarding the existing urban structure. An important quality of the plan is the integral approach for solving more and more urban problems, especially infrastructural systems (planning of the street web and the tram routes). Due to the Balkan Wars and the First World War, the implementation of this planning concept is not realized, but it has a tremendous impact on the further development of the urban planning in Skopje [26].

In the period when it comes to the competition work, the region of the Skopje valley is territorially part of the Kingdom of Serbia. Then Skopje has 47,384 inhabitants [25]. In that period there was no specific legislation that treated urban planning. It is regulated by the document "Decree on occupations of civil in the liberated and assigned areas of the Kingdom of Serbia". The surface of the mountain range is about 1,112.26 ha, which is three times larger than the existing area of the city, which is about 357.02 ha.

*General Regulation Plan for the city of Skopje from 1929*

The General Regulation Plan for the City of Skopje from 1929 is the first official planning document for the city which enroots the development of Skopje as contemporary European city. The planning solution presents continuation of the morphological and program matrix of the plan of the architect D.T. Leko, but redefining the irregular web (out of respect for the cadastral ground) in more expressive formal, geometric matrix.




**Picture 5.** General Regulation Plan of the City of Skopje, R = 1:5.000, 1929 [3].

Author of the plan is the architect Josif Mihajlovikj, originating from Tresonche, gaining education in Skopje, Thessaloniki and Belgrade, specializing and mastering in Europe and America.

He was Skopje's mayor and governed the construction department. Having in mind the city problems, he resolved crucial and significant issues with the plan. For the needs for the documentary base of the plan a cadastral measuring of the city was done for the first time. The city structure was more built on the right bank of the Vardar river, and more constructional activities were carried out in the south-eastern part of the city. The old Ottoman part on the left bank is abandoned, while the new web is spread on south.

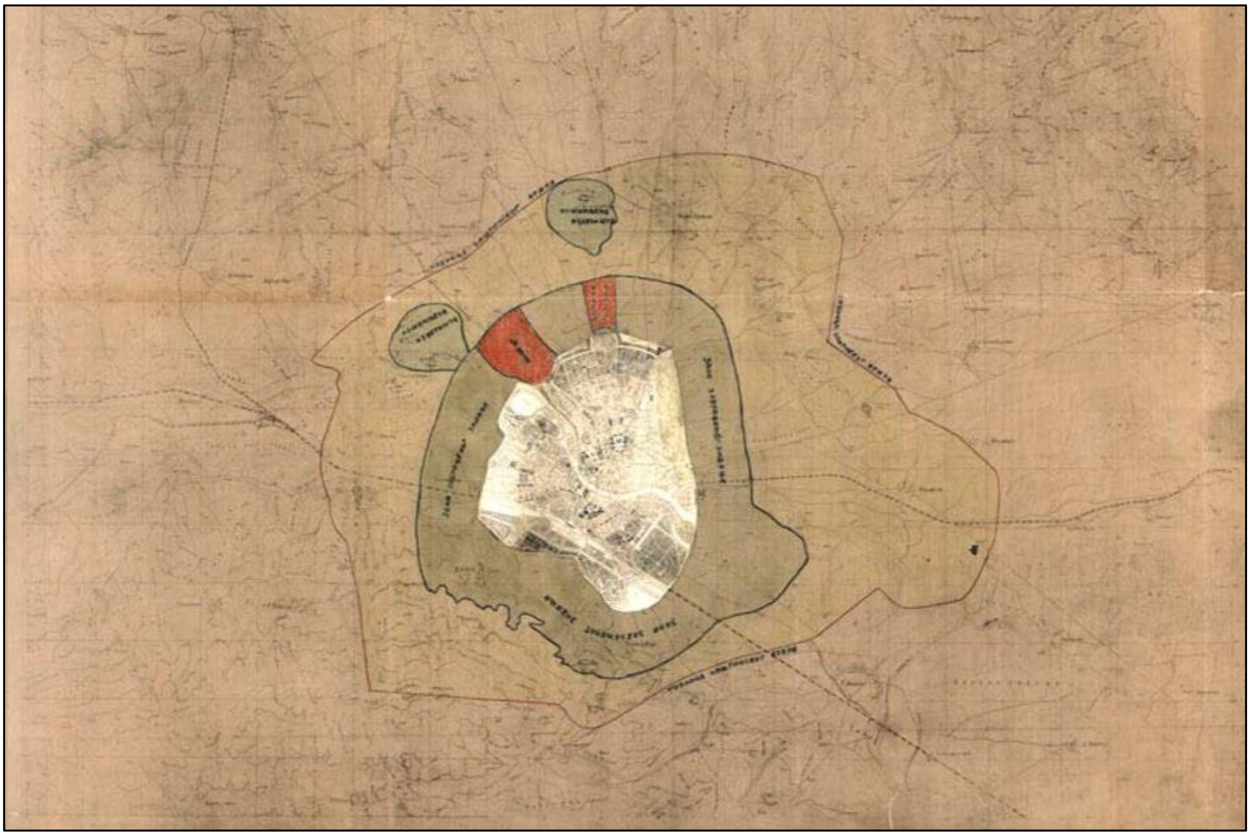
It is worth mentioning the following infrastructural objects:

- the construction of contemporary water supply system from the headwater Rashche
- the construction of power plant under Kale
- the dam of the Treska river and the hydroelectric power plant Matka and others.

Under Mihalovikj's government and authorship a lot of public objects have been built. They are protected as cultural heritage even today. In the concept for modern urbanization many possibilities were projected for Skopje to become developed and hygienically healthy city. Thus, for the first time, a crucial attention is paid to the green park areas. The concept of cities-gardens and open construction system are projected on the outskirts of the urban surfaces.

The social-political conditions that governed this period when implementing this General Regulation Plan are extremely complex, thus, the plan is important as both planning document and instigator of the city development. During that period, Skopje becomes more important as a center to a bigger territory than before. After the First World War it becomes center of the Skopje District (one of the 33$^{th}$ districts of the newly established Kingdom of Serbians, Croatians and Slovenians (the so-called SCS Kingdom in 1918) and finally resulting in center of the newly formed Vardarian Banovina. Regarding the legislation, according to the periodization of Siljanoska [29], or the period from 1914-1948: a period where an urban activity and legislative material are established through which an integral treatment of all aspects important for control of the spatial-physical development of the city is ensured. The planning area of the city is around 1.192 ha, and according to the author the planning solution has the capacity of providing housing for 120-150 thousand residents. Skopje had 40.660 residents in 1921 [25].

It is important to note that the General Regulation Plan for Skopje treats the wider surrounding of the city as well. For this purpose, a special graphic representation was made where the opinion on the controlled expansion of Skopje can be noticed, together with the creation of a green belt-ring, 1km wide, where constructions would be banned [24,26].



**Picture 6.** Map of Skopje with surroundings, situation in1929 [6]

*General Regulation Plan of the city Skopje from the Czechoslovakian architect Ludjek Kubesh 1948*

After Second World War there is a new era in the urban planning of Skopje. With the new social-political conditions Macedonia is part of the Federative National Republic of Yugoslavia, as an independent country, and Skopje is the Capital of the Republic of Macedonia.

The capitalistic system is replaced by socialist system that was oriented towards equality. As a result of the war, cities are generally destroyed, there are human loses, economic poverty and destroyed economy. In the urban planning, a new concept is implemented which is based on the postulate of the "Functional city" and the Athens Charter of CIAM from 1933, covering the provisions for: division of the city functions, pleasing the enhanced necessity for speed and time saving, establishing relation with the region, establishing programming of the needs and the overall analyses of the natural and assigned factors, introducing humane dimension, establishing the initial nucleus (habitation) and forming residential units, and placing the public interest above the individual one.

In 1948, the architect Ludjek Kubesh elaborates the General Regulation Plan for Skopje, following a direct draft from the Czecho-Slovakian engineers from the Architectural studio from Prague (Atelier architektů - Praha Skopje) and Macedonian experts.

**Picture 7.** General Regulation Plan of the City of Skopje, R = 1:10.000, 1948 [5]

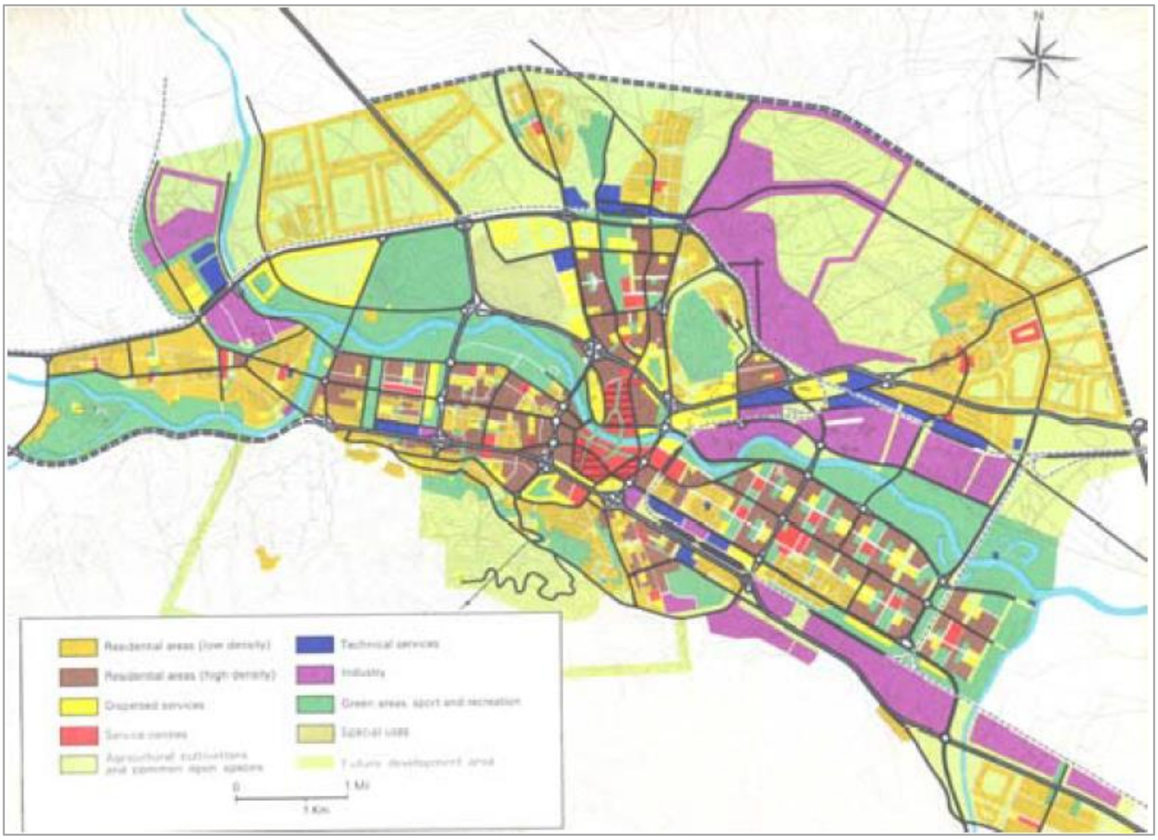
The Constructional Law from 1931 is a basis for development and implementation of the plan, as well as the Basic Construction Regulation act from 1948 and the Basic Design Projection Regulation act from 1948, which have been adopted for the needs of rebuilding the cities after the war. The plan is different from the Regulation framework in such a way that is a free conceptually developed document which supports the" functional city" in the sense of: zoning the main city zones (industrial, business and residential), providing efficient transport system, providing an open space near the functional zones and allowing proper suburbanization.

Skopje in 1948 counts 102.600 residents, so the increase of the population from 1929 to 1948 generally happens in the same urban area, with a slight augmentation of the constructed area. The high population growth is concentrated in Bunjakovec, which territorially covers almost half of the existing city. The plan contains an area of 4.637 ha, but broadly speaking, it defines the area of the so-called "Big Skopje" with 9.676 ha.

With this plan, the city undergoes fast development. Following the tendency to industrialization, Skopje is considered as a center of a wider gravitational area.

Special important qualitative segment of the plan is the solution on the traffic infrastructure. A hierarchy of the traffic corridors is made, so intercity transport and surrounding area traffic is included in the traffic concept. For the first time a ring road is planned on the western, northern and eastern margin of the city. Railway lines compose a close circle system around the city, which marks the border of the city constructional region, and connects it with the region and the world. The projected connection between the industrial complexes and the railway lines is of special interest.

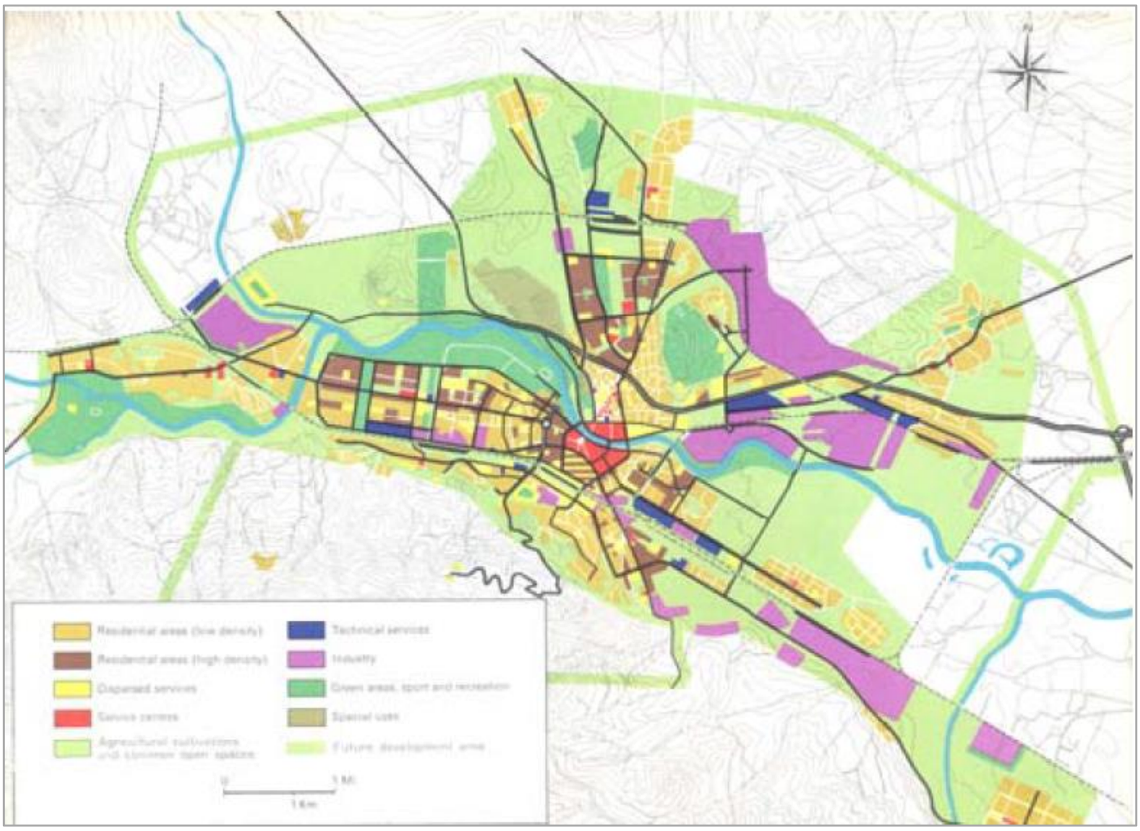
This plan includes the air traffic for the first time - planning for a new airport in the north-west, or south from Zajchev Rid. Probably the bravest move in the plan is treating Vardas as sailing river.
The plan has resulted in changing of the city image. The rapid growth of the population in the city arose the need for plan revision, which was made in 1955. The revision stipulates enlargement of the city with a housing zone around Zajchev Rid with capacity of 30.000 residents. Thus, in 1961, the population number has increased up to 165.000 residents, and there was a need for another revision of the plan. With the second revision the city area increased from 4.637 ha to 6.142 ha, while the area of the wider region remains relatively the same (from 9.676-9.791 ha). A demographic study is carried out which stipulates that the population will increase up to 400.000 residents, resulting in projected density of 73 residents/ha [26].




**Picture 8.** Land use and zone plan for 1971 [14]

*Basic Urban plan of Skopje, made by "Polservis" from Warsaw, "Doksijadis" from Athens and the Institute for Urbanism and Architecture of Skopje from 1965*
The Basic Urban Plan of Skopje from 1965 is made by "Polservis" from Warsaw, "Doksijadis" from Athens and the Institute for Urbanism and Architecture of Skopje, which included numerous world and native experts that elaborated a lot of all-embracing studies. This plan was being developed in relation to the rebirth of Skopje after the catastrophic earthquake on 26.7.1963. The plan is made under the auspices of The United Nations, where a special trust fund is formed and the whole operation is about humanity and solidarity from countries from all over the world, and due to this unfortunate circumstances, it brought worlds' attention to Skopje and it is known as "the most famous urban plan of Skopje".
The plan operates in accordance with a new methodology of all-embracing planning, so it includes economic, social and ecological aspects. The city is considered in wider context of the regional planning, as a center of a bigger sub-region that steps out of the frameworks of then SRM and has an impact on whole Kosovo, Metohija and South Serbia.
In reviewing the elaboration of the Basic urban plan, the whole Skopje Valley is taken as a territory, 47 km long and 50 km wide. In 1965, when the development of the plan started, the Skopje region counts 312.000 residents and it is divided in 3 municipalities, that cover territories of the city of Skopje [14]. The initial territory chosen for the plan is 9,090 ha, while it finally covers 11.556,7 ha. For detailed analyses an area of 4,215 ha is planned, which also covers the area of the "city center" of 290 ha. [14]. In this period the city counts 219.989

citizens, and for the purposes of the planning two planning periods are considered: first period until 1971, with population growth to 270.000 citizens, and second until 1981, with population growth to 350.000. The basic urban plan from 1965 is made as a typical zone plan, which is a general regulation plan, and it is a basis for further elaboration with adoption of detailed urban plans that must establish the directions for city development and contruction. Therefore, city borders for two developing eras until 1971 and 1981 are determined, and the city is divided in zones (according to land use) and urban units. These two categories were introduced for the first time in the urban planning of the city.




**Picture 9.** Land use plan and zone plan for 1981 [14]

The plan focuses on the industry – the main driver of future development. Expansion of current and construction of new capacities are projected. Industry classification is also made according to the pollution level, and proper location of the industrial capacities is determined. Heavy industry is located out of the city, while light industry is located following the equal placement principle in the urban territory.

According to the system of hierarchy, public functions are given to centers with local, regional and city characteristics.

The traffic concept is defined according to the basic relief of Skopje Valley and the flow of the Vardar River, mainly in direction NW-SE. City high ways (express magistral) are established that tangentially touch the city center. Traffic arteries are classified into express magistral, magistral streets, gathering streets and their intercrossing on more levels or at the same level.

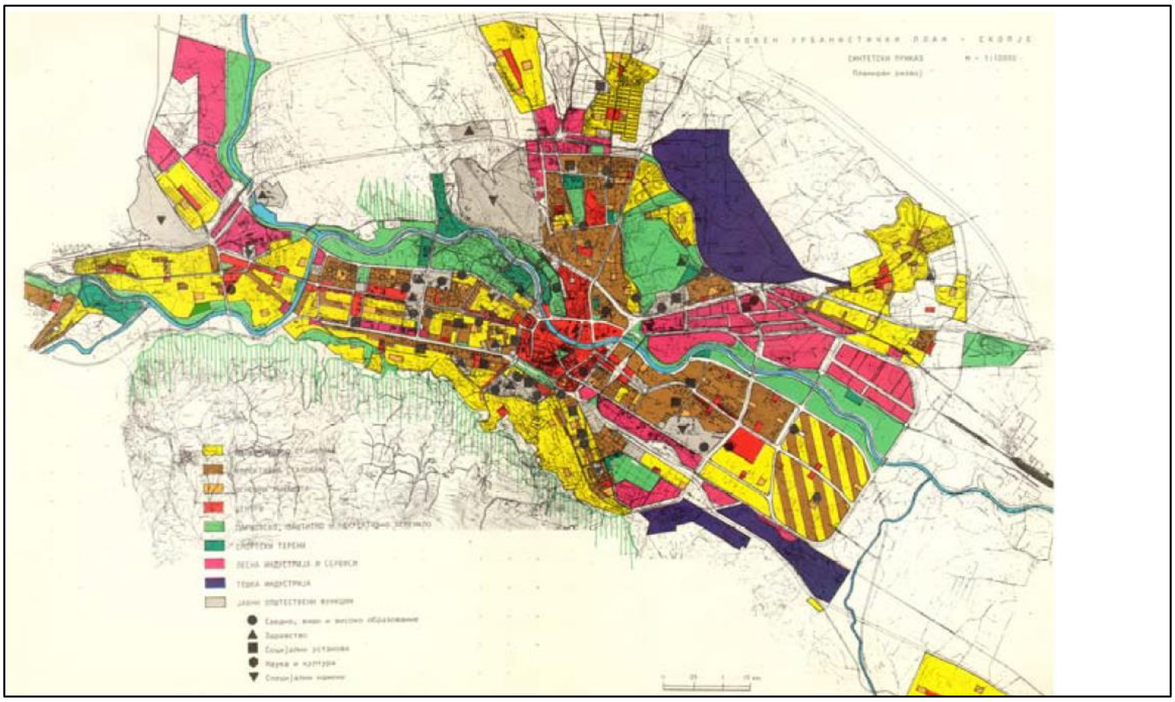
The plan also makes thorough changes to the railway traffic system as well as impacts its full reconstruction. [12]. The southern railway route is stopped (the authors of this article believe this was a serious mistake) and it became a car corridor – South Boulevard (Juzhen Bulevar). The main railway station is dislocated among the settlements Aerodrom and Prolet, while the old object is transformed into Museum of the City of Skopje. A division of the systems of passenger and freight traffic is also made, with common stations in Gjorche Petrov, Madzhari and Drachevo as entrance stations in Skopje and the station Skopje-North. Connections of product supply and delivery is organized from big factories, and the factory Zelezara gains its own internal system.

In this plan the idea for water traffic and flowing Vardar River is completely dismissed, and changes are planned for the air traffic also, with the dislocation of the airport from the city borders, to the east, where the airport "Petrovec" has been formed, today known as "International Airport Skopje".

Greenery receives special treatment with this plan, as a developed system of green recreation areas. Local, regional and city parks are introduced with

connected green corridors to the greenery from the outskirts. The plan specifies big green areas outside the city (Vodno and Skopska Crna Gora mountains), which are planned as big park-forests. Several tourist-recreational centers such as Matka, Rashche, Volkovo, Katlanovo, Zelenikovo and others are also planned.
A very special component of the plan is the appendix with recommendations for further implementation of the plan stated in the section called “Realization” [14]. Realization is divided into “Every-day Realization of the Actual Problems” and “Rules of Realization”.
The plan covers area of 11.556,7 ha. The planned number of 270.000 until 1971 (which was supposed to increase up to 350.000 until 1981) was surpassed, so in 1975 the population counted 352.000 residents [11, 26].

*Basic Urban Plan of the*
*City of Skopje – Amendments, 1985*
The Basic Urban Plan of the City of Skopje from 1985 is made by the Institute for Urbanism and Architecture of Skopje, under the auspices of Blagoj Kolev, Phd. The plan follows the principles from the previous BUP (Basic Urban Plan) from 1965 and it makes necessary adjustments to the current situation.

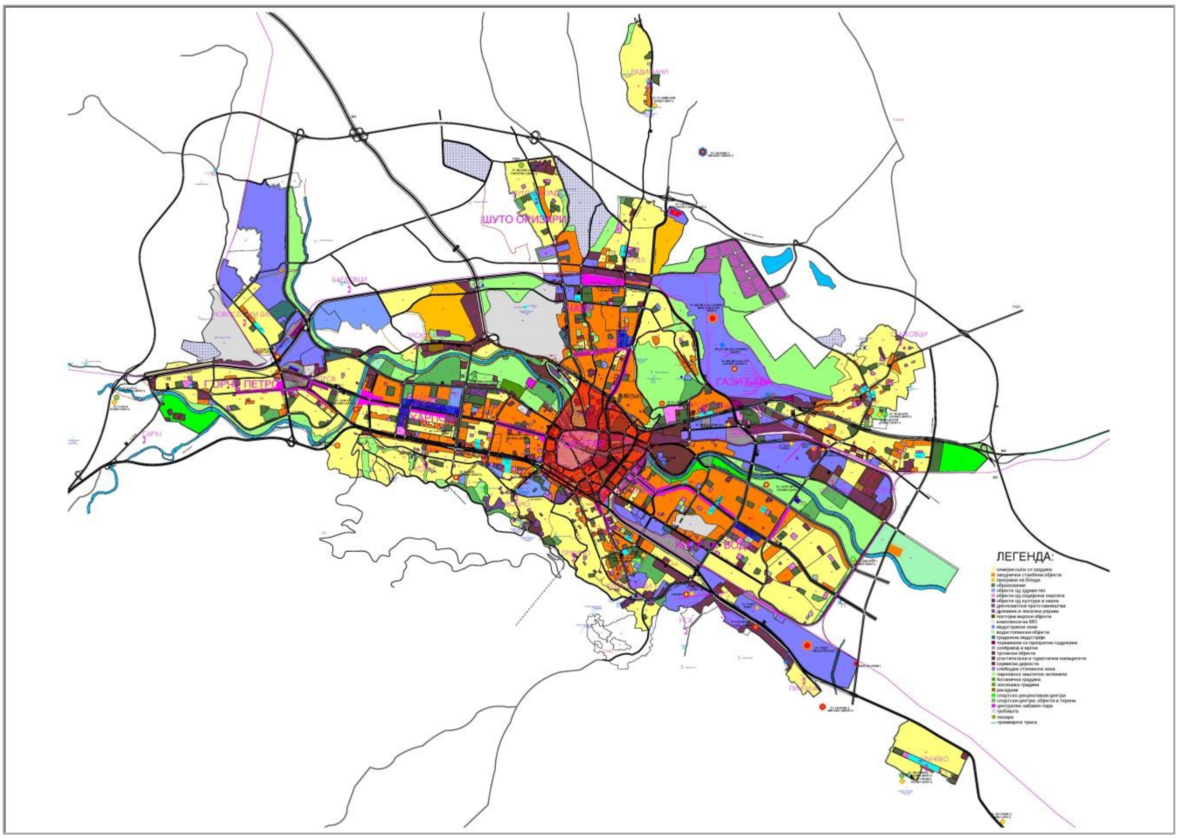


**Picture 10.** BUP Skopje 1985 – Synthesis presentation/plan [15]

The drawing up of the plan is carried out at the same time with the processing of the Spatial Planning of the RM and the Spatial planning of Skopje. The social-political conditions are relatively stable, Macedonia is still part of the SFRY, but one can feel the beginning of the stagnation of the social-economic development. In the planning solution “municipalities” (as basic cells of the social-political organization) are introduced - an obligation from the Constitution of SFRY from 1975. The introduction of these units causes problems because the borders of the urban units defined in the plan often don’t correspond with the territories of the municipalities. The legislative framework for drawing and adopting the plan is defined by the “Law on Spatial and Urban Planning” from 1978. According to Siljanoska, this law belongs to the third period of the legislation or the “period of enlarging the control instruments important for shaping the city space” [29]. It is worth mentioning that the plan contains “provisions for realization”, In the plan, Skopje is treated in broader regional context (Kumanovo, Veles, Tetovo), while the concept of rings (central, middle and peripheral) is considered at a city level.
During this period the city had 409.000 residents. There was a great realization of the planned contents from the previous plan, and there were larger number of residential units than of families (tendency to own more flats and immigration of people from the inner parts of Macedonia and the wider region of Kosovo and South Serbia).
The traffic concept from the previous plan is still present. A division in primary and secondary street web is introduced. The primary is defined by the Basic Urban Plan, while the secondary by the detailed urban plans. This plan shows a great level of realization in the residential construction, but the

planning web of traffic artery is not implemented completely, and that leaves consequences until today.

Almost all of the planned industrial capacities are built, but the stipulated dislocation of the existing factories in the central city area is not completed.




**Picture 11.** General Urban Plan of Skopje, 2002 – Synthesis plan [18]

*General Urban Plan of the City of Skopje from 2002*

The stated planning concept in the plan from 1985 is continuously upgraded and the latest amendments of the GUP in 2002 contributes to a great extent to keeping the established borders from the previous plan with an area of 7.656,4 ha [11]. The plan is in accordance with the Law on Spatial and Urban planning [28]. The planning solution defines the land use and its implementation is not direct, it is further developed through drawing up and adopting Detailed Urban Plans [17]. The number of residents is planned in two planning periods: 582.300 residents until 2010 and 614.400 until 2020.

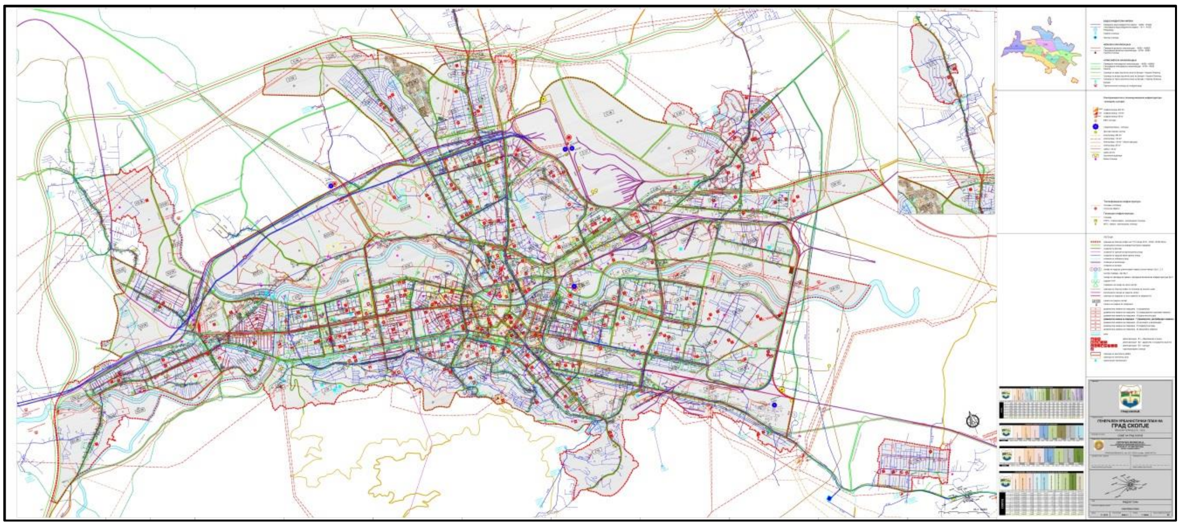
In relation to keeping the urban area, due to growth of the population number, enlargement of the population concentration is stipulated in the housing zones, and especially in the zones for individual housing, as well as rebuilding the dense central city web by finishing the current perimetric city blocks and forming new ones. The implemented concept of the spatial non-development of the city is justified, except to the expansion of the working zones along the magistral exit road directions. From current point of view, it is noticed that this planning concept is in direct collision with the phenomenon of illegal construction and the treatment of such, defined by the law solution of the Law on Procedure for Illegally Constructed Objects [17].

The organization of working zones in the plan stipulates usage of the already built capacities and maintaining the three industrial zones, and the north-eastern zone enlarges with the free economic zone “Zhelezara”. In the plan the urban planning approach is based on contemporary standards of sustainable development and protection of the environment (dislocation of factories “Alumina” and “Treska”) as well as construction of new high technical-technological capacities by engaging highly productive staff.

A special attention is paid to greenery, strict provisions are defined in such a way as to guarantee its protection – “areas aimed for greenery, sport and recreation shall not to be used for other purposes, at the same time, all areas planned for public use and other uses shall be protected by erecting green areas until the plan is realized” [17]. However, park-forests such as “Gazi Baba”, partially “Vodno”, “Saraj”., the City Park, Kale and Zajchev Rid are still maintained, but not the near-river greenery along the Vardar River.

The traffic concept follows the concept of the solution from previous plans. There is a tendency to constructing public car parks in the central region.

*General Urban Plan of the City of Skopje, 2012*
The planning concept of the latest adopted general urban plan for Skopje is based on the concept of The General Urban Plan of the City of Skopje from 2002 (planning period 2001-2020), the analysis of the space and the possibilities for spatial development. The planning documentation is defined by the Law on Spatial and Urban Planning [28], the Rulebook on standards and norms for urban planning and the Rulebook on detailed contents, scale and methods of graphic processing of urban plans. The plan is strategically developed document with general elements of spatial development that has to be realized following regulation plans and detailed urban plans. The plan defines 162 units-fourth for further elaboration.



**Picture 12.** GUP Skopje 2012 – Synthesis plan [18]

The surface area of the plan is 8.790 ha, including Radishani and Drachevo, as well as the borders of the GUP Saraj, which are now included within the city borders [28]. When determining the urban area, a special attention is paid to the aspect of reserved surface, for the post-planning period. This reserved surface is planned to have the role of a tampon zone between the constructed built surface in the city and the rural populated places, which would be agricultural until its function is changed (resulting in ruinous approach for Skopje considering the biological capacity of the geographic space of the valley).

**Picture 13.** GUP Skopje 2012 – Function plan of the land – function zones [18].

The planning development of the contact area of the city in the future is expected to exclude Drachevo, Radishani and Saraj into satellite city neighborhoods containing urban features outside

the city of Skopje. Expansion of borders is also expected with the locality of Penitentary “Shutka”.
Expansion of the urban area is also projected in the working zone Pintija (along Drachevski road) with the purpose of complex and integral regulation of the construction of industrial buildings, as well as of numerous localities with illegal constructed buildings. Apart from expansion of the stated parts, the plan stipulates excluding of spaces between “Zhelezara” and lake Smilkovo from the borders of GUP, or in other words, the space between the zone for technological-industrial development adopted in the GUP of Skopje from 2002, and the space between “Novo Selo” and “Lepenec”, projected for expansion of the western industrial zone. To determine and direct the development of the contact settlements, planning solution defines the detailed tracks for constructing entry-exit magistral and regional traffic arteries.
The population of the city of Skopje shows less growth dynamics in comparison with previous decades. According to the expectations in the plan, in 2012 Skopje would count 613.047 residents, while in 2021 647.950 residents [18]. According to the projections (medium variant) of the United Nations (UN) a decrease in the population number is assumed – from 2010 a negative increase of 0.04 percent is expected, while in the period 2007 – 2050 - 14, 4 percent.
In relation to the production activities, the planning solution respects the existing city industrial zones and individual production buildings spread in the urban city web. Planning provisions are directed towards the three formed zones - north-east, south-east and west. Pollution capacities are tended to be dislocated outside the city (as stipulated in the previous GUP as well). Industrial activity development is also projected in new spaces outside the planning area of the GUP of Skopje. In planning these spaces, the technological-industrial zones occupy a special place. The concept supports the formed economic zones, located outside the city, TIDZ (technological industrial developing zone) Skopje 1 (140 ha) and TIDZ Skopje 2 (97 ha), already being infrastructurally equipped.
One of plan’s aims is to create conditions for development of several rural centers outside the city area for decreasing the mechanical flow and for redistribution the city population. Due to city domination and polarization in relation to other cities, it is necessary for regional and national purposes to set balance on the development of Skopje as metropolitan concentrated region. This assumes establishing proper regional politics that would enable balanced development by effectuating the developing potential of other cities and regions. Following this approach, Skopje would have the development perspective of a first-rank city at a higher qualitative level. Therefore, the development of the city can be directed to tertiary and quaternary activities.
Regarding the system of centers, the plan stipulates introduction of fifth-degree centers in suburban settlements, changing the functions of the space for cultural centers, park-entertainment centers, malls, social/public buildings. Examples of such current industrial complexes are: “Treska”, “OHIS”, “Cementarnica”,” Imperial Tobacco” and others.
The aspect of greenery in the plan has all-embracing treatment approach, but the practice is opposite of the planning stipulations.
The plan defines localities and building that are outside the planning area of the city but are especially important for functioning of the city systems. Those are headwaters “Rashche”, the city airport, “Drisla” landfill and others.

**Analysis of the territorial expansion of the city**

The analysis of the territorial expansion of the city is made with the help of a method for comparing-overlapping the surfaces of urban areas of urban plans. Based on the hereby said, a documentary basis is made as a foundation for elaborating the urban plans. The estimated measures are plan-by-plan and integrally discussed.

**Table 1.** Preview of surfaces of existing situations and planning areas of urban plans (ha)

| period (ha) | General Regulation Plan, 1914 | General Regulation Plan, 1929 | General Regulation Plan, 1949 | Basic Urban Plan 1965 | Basic Urban Plan 1985 | General Urban Plan 2002 | General Urban Plan 2012 |
|---|---|---|---|---|---|---|---|
| situation | 357,0 | 796,2 | 625,9 | 4.104,7 | 4.755,2 | 7.088,0 | 8.464,0 |
| area surface | 1.112,3 | 1.192,9 | 4.637,0 | 11.556,7 | 6.844,9 | 7.656,4 | 8.790,0 |
| surface increase | 755,2 | 396,7 | 4.011,0 | 7.454,9 | 2.089,8 | 568,4 | 326,0 |

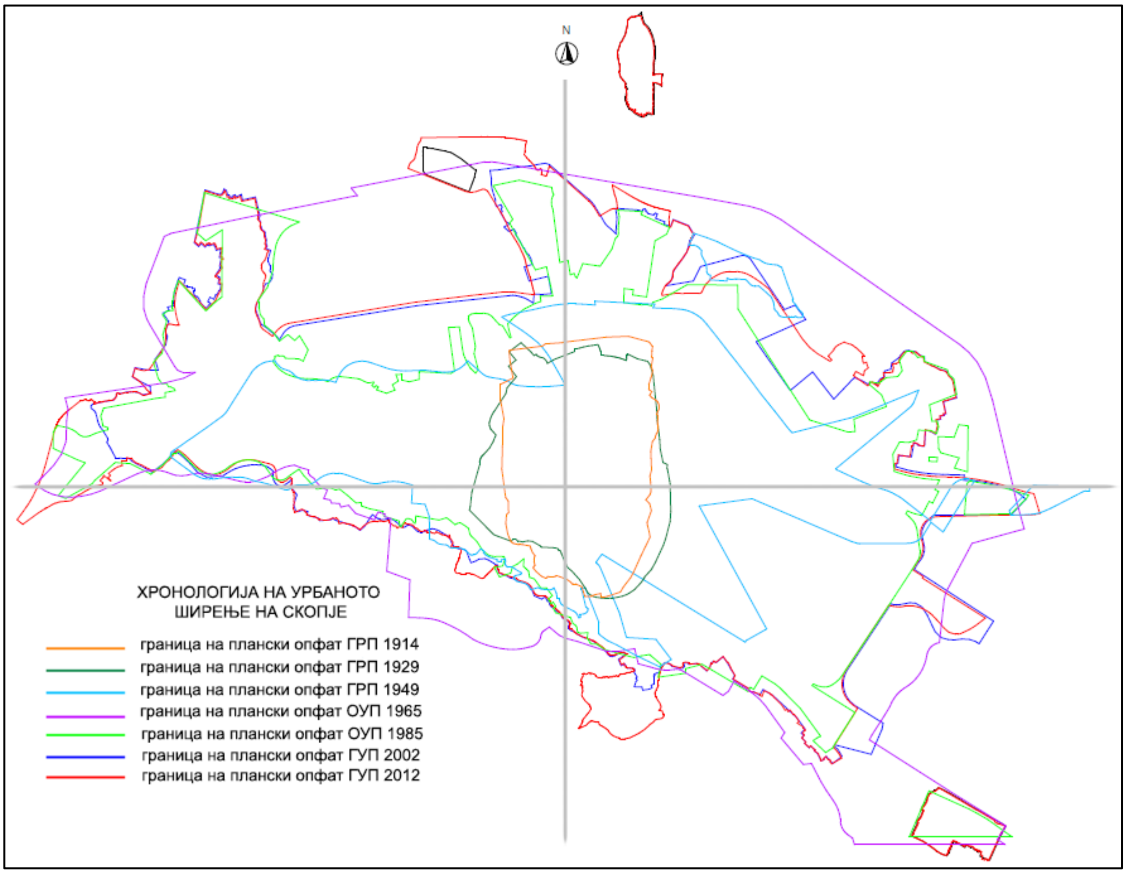
Source: [2,3,4,5,6,8,9,10,11,12,13,14,15,16,17,18, 26]

*General Regulation Plan, 1914.* The city borders as continuous situation defined for elaboration of the competition study od D. Leko covered a territory of around 357 ha. With the competition plan, although the city borders are not precisely defined, a city development with an area of around 1.113 ha is projected, which is practically an increase in the territory of 756 ha (67%) or augmenting the existing condition three times. The expansion is stipulated for all parts, except the eastern.

*General Regulation Plan, 1929.* With this General Regulation Plan from 1929 the territory is 1.192,88 ha, which contributes to increasing the existing constructed structure of 33 % - 396,7 ha. With this the area of the existing city is increased by 50%. Bigger expansion is projected in the north-west, and smaller one in its eastern border.

*General Regulation Plan, 1949.* The General Regulation Plan from 1949 includes the most radical changes regarding territory. An expansion of the existing structure towards all sides is stipulated, the southern part has certain limitations due to its relief features ("Vodno"). The biggest expansion is in the east-west. The new borders of the city area change the whole physiognomy of the city, with dominantly east-western axis. The new planning area is 4.101, 7 ha, which is an increase up to six and a half times from the existing city. The expansion is 84% of the urban area.

*Basic Urban Plan, 1965.* The Basic Urban Plan for Skopje from 1965 is a more strategic document with two planning periods - 1971 and 1981. The analyses use foundations from 1981. The borders in this plan are not precisely determined, and the zone plan was being used for comparing. This plan also stipulates augmentation of the territory up to 7.454,97 ha (which is 64% from the area) or increase in 2,8 times of the existing condition. The border expansion includes all directions, except the southern part due to location of the natural borders – the slopes of Vodno. The plan proposes large reserved areas for future expansion of the city.




**Picture 14.** Planning area of the GUP of Skopje in the period 1914-2012 [18,26].

*Basic Urban Plan, 1985* – amendments. The amendments of the Basic Urban Plan from 1985 follow the planning concept of the previous plan from 1965. However, this plan is the first plan to propose decreasing in the city borders and more realistic planning of the future construction and the rational connection by covering the surrounding territories. The border, or the territory of the planned urban area is 6.844,96 ha which presents decrease in 59% in comparison with the BUP from 1965. Regarding the existing situation the new area includes increase up to 1,4 times of the city territory. Territorial decrease is planned almost in all peripheral areas, but mostly in the northern part from Zajchev Rid and in the direction towards Skopska Crna Gora, and v. Lisiche.

*General Urban Plan, 2002.* The planning area of the General Urban Plan from 2002 follows the condition that is marked in the document foundation and stipulates slight increase of 568,4 ha, which is around 7 % of the planning area of the existing situation.

*General Urban Plan, 2012.* The General Urban Plan from 2012, adhering to the concept of rational use of the land, follows the existing condition of the city and plans an area of 8.790 ha, which includes expansion of 506 hectare (including Saraj) which is around 5,7 % of the planning city territory.

Due to clearer identification of the borders of spatial expansion of Skopje, in picture 13 the chronology of planning areas overlapping in all urban plans for the city is presented. The borders themselves of the urban plans demonstrate the presence of rapid expansion of the urban part of the city. However, apart from planning territory expansion, the results from the researches are threatening because they point to seriously high rate of land sealing, in the shape of land degradation, where in the period 1965-2010 unproductive land in the region of Skopje is increased up to 63 %, that is – 0,14% annual rate regarding the whole land, or 0, 24% average annual loss of the arable land [30].

## CONCLUSION

Having in mind all elaborations, we can conclude that the planed urban development of Skopje starts in 1914, where the area of 357 ha is increased to 1.112 ha (the plan makes a triple increase of the urban tissue), following the matrix of European contemporary cities. The development continues along with the next plan in 1929, which stipulates an area of 1.192 ha. This plan is characterized by slight increase in the planning city borders, on a foundation of a constructed physical structure double sized then in 1914. The following plan in 1949 covers a post-war period and big changes in the society and the social-political system. This plan supposes big expansion of the area – 4.101,7 ha, which is six times more than the existing urban web. The biggest expansion is stipulated with the plan from 1965 after the earthquake, where the planned area is 11.556,67 ha. However, in the next plan from 1985 there is a decrease in the city borders and the territory is 6.844,96 ha. The plan from 2002 projects a city area of 7.656,4 ha, while in the latest GUP from 2012 the city borders cover 8.790 ha. This means that with the planning development of the city of Skopje during a time span of 100 years (103), starting from a present condition of 357 ha in 1914 to planning development of 1.112 ha, Skopje has reached an existing condition of 8.464 ha with planed urban area of 8.790 ha. The planning urban area in this period of more than 100 years stipulates increase in the city borders six times more, while the existing condition of that period has increased by more than 23 times.

These numbers present a significant growth in the borders of Skopje, covering its territorial expansion of the space of Skopje Valley, raise an inevitable question about politics of sustainable development, rational use of the land and protection of the agricultural land and forests. Taking the geographic space of the valley and the biological capacity into account it is estimated that the ecological rate of valley exhaustion is 4 times higher than the natural capacity [33].

Due to the complex structure involving different segments and their interrelations there is a need of all-inclusive analysis. In this way we can receive an integral representation of the occurrence and its meaning in general. The research has to provide the interrelated differences, the conflict points and the negative effects of the urban expansion of the city web at the expense of elements for sustainable development and rational usage of the land, protection of agricultural land and forests. When determining the proper program-spatial matrix as a tool for spatial planning, apart from all aspects of the existing condition, the inventory, the relations in the urban web, the relations between the urban and the rural sections, the needs, the spheres of interest, the possibilities for alternative and multi-purposeful use, as well as the conflict points in using the land, the developing line should be based on the strategic theses of the European Union for spatial planning which are mainly oriented towards polycentric and balanced spatial development, integration of the urban and rural environments, territorial integration in the inter-border functional regions, providing competition in regions based on strong local economies, improving communication infrastructure between the population and the community and the economy. This can be done if all aspects of protecting and enhancing the environment and the cultural goods are taken into account [32].

## REFERENCES

[1] Agency for Spatial Planning of the Republic of Macedonia (2010): Spatial planning of Skopje Region 2005-2020 – Draft. Skopje: Assembly of the Republic of Macedonia

[2] Agency for Spatial Planning of the Republic of Macedonia (2012): General Urban Plan of the City Skopje. City Skopje Council, Skopje.

[3] Archive of Macedonia, arch.no. AM_1.872.20-9

[4] Archive of Macedonia, arch.no. AM_1.872.20-10

[5] Archive of Macedonia, arch.no. AC_6.76.522.1

[6] Archive of Macedonia, arch.no. AM_1.872.20-88

[7] Government of the RM (December, 26, 2010): Decision on determining the nomenclature of territorial units for statistics – NTUS, no. 19-7957/1, Skopje

[8] Institute for Urbanism and Architecture of the City of Skopje, Doksijadis Company – Consultants for development and ekistics (1964): BUP Skopje preview of constructed surfaces. Book 6. document ЗУА-СК -10, ДОКС-ЈУГ. A2 (30-4-65), prepared for United Nations and the city assembly – Skopje, Skopje.

[9] Institute for Urbanism and Architecture of the City of Skopje (1964): BUP Skopje urban study – Reviews, recommendations, conclusions, book 4, Skopje

[10] Institute for Urbanism and Architecture of the City of Skopje (1964): BUP Skopje spatial concept, book 5, Skopje

[11] Institute for Urbanism and Architecture of the City of Skopje (1965): Basic urban plan of Skopje, book 1-21. Skopje.

[12] Institute for Urbanism and Architecture of the City of Skopje (1965): Basic urban plan of Skopje, book 12. Skopje.

[13] Institute for Urbanism and Architecture of the City of Skopje (1965): Regional plan of Skopje, book 14, Skopje.

[14] Institute for Urbanism and Architecture of the City of Skopje (1965): Basic urban plan of Skopje, book 15, Skopje.

[15] Institute of Urbanism and Architecture of the City of Skopje (1965): Basic plan of the City Skopje, Assembly of the City of Skopje, book 7. Skopje.

[16] Institute of Town Planning and Architecture – Skopje (1965): MP Skopje – Summary of the report on the master plan, book 8. Skopje.

[17] Public Enterprise for Spatial and Urban Plans (2002): General Urban Plan of City Skopje, Assembly of the City of Skopje, Skopje

[18] Public Enterprise for Spatial and Urban Plans (2012): General Urban Plan of City Skopje, Assembly of the City of Skopje, book 1-2, Skopje

[19] Korobar, P.B. (1984): Spatial and Physical Courses of the Reurbanisation of the Example of the City of Skopje, Master study, University of Ss. Cyril and Methodius, Faculty of Geography, Skopje (Translated from the original: Коробар, П. В. (1984): Просторно физичките текови на реурбанизацијата на примерот на град Скопје, Магистерски труд, Универзитет "Кирил и Методиј", Географски факултет, Скопје)

[20] Kubesh, L. (1949): General Regulation Plan for Skopje 1948. Government of the RM, Skopje (Translated from the original: Кубеш, Л. (1949): Генерален регулационен план за Скопје 1948. Влада на НРМ, Скопје).

[21] Markoski B. (1992): Cartography Cartometric Studies on Hypsometric Structure of the Space and Location of the Population in the Republic of Macedonia, Phd dissertation defended at the Institute of Geography, Faculty of Natural Sciences and Mathematics, Skopje (script). (Translated from the original: Маркоски Б. (1992): Картографско картометриски проучувања на хипсометриската струкрура на просторот и разместеноста на населението во Република Македонија, докторска дисертација одбранета на Институтот за географија при ПМФ, Скопје. (ракопис).

[22] Markoski, B (1995): Hypsometry of the Space and Population in the Republic of Macedonia – Cartographic method. Macedonian treasury – Kumanovo (Translated originally from: Маркоски Б. (1995): Хипсометрија на просторот и населеноста во Република Македонија - картографски метод. Македонска ризница – Куманово.)

[23] Markoski B (2005): Cartographic preview of the Spatial expansion in Skopje, Study Collection of scientific gatherings "Aspects of the urban development and contemporary urban practice in Skopje", Skopje. (Translated originally from: Маркоски Б. (2005): Картографски преглед на просторното ширење на Скопје, Зборник на трудови од научен собир "Аспекти на урбаниот развој и современата урбанистичка пракса во Скопје", Скопје

[24] Mihajlovikj, J (1929): Regulation Plan of Skopje, Skopje Bulletin, 1929, no. 28, 30, 31, 32. National and University Library "St. Climent Ohridski", Skopje. (Translated originally from: Михајловиќ, Ј. (1929): Регулациони план Скопља",Скопски Гласник, 1929, бр. 28, 30, 31,32, Национална и универзитетска библиотека „Св. Климент Охридски", Скопје.

[25] Panov, M. (1976): Geography of Macedonia – natural and socio-geographic characteristics, book 1, Prosvetno Delo, Skopje. (Translated originally from: Панов, М. (1976): Географија на Македонија -природни и социо-географскикарактеристики, Книга 1, Просветно дело, Скопје.

[26] Penchikj, D. (2011): Influence of the urban plans on discontinuous spatial transition of the city Skopje in the twentieth century. Phd dissertation. University of Ss. Cyril and Methodius – Facutly of Architecture, Skopje. (Originally translated from: Пенчиќ Д. (2011):Влијание на урбанистичките планови врз дисконтинуираната

просторна транзиција на градот Скопје во дваесеттиот век. Докторска дисертација. Универзитет “Кирил и Методиј”- Архитектонски Факултет, Скопје).

[27] POLISERVIS –Konsultanti inzenjeri, Varsava, Polska, pretstavnik Instituta za urbanizam Varsava, i Zavod za urbanizam i arhitektura grada Skopja, SFR Jugoslavija (1965): MP plan prigradske zone Skopja. Knjiga 16, Izvestaj pripremljen za ujedinjene nacije kao izvrsne agencije ujedinjenih nacija. Skopje.

[28] The Offical Gazette of the Republic of Macedonia: No. 51/2005, 137/2007, 151/2007, 91/2009, 124/2010, 18/2011, 53/2011, 144/2012, 55/2013, 163/2013 and 42/2014, Skopje. Law on Spatial and Urban Planning

[29] Siljanoska, J. (2001): Planning aspects of shaping the city space, Phd dissertation, University of Ss. Cyril and Methodius, Faculty of Architecture, Skopje. (Originally translated from: Сиљаноска, Ј. (2001) Планерските аспекти на обликувањето на градскиот простор.докторска дисертација, Универзитет “Кирил и Методиј”, Архитектонски факултет, Скопје).

[30] Trpchevska-Angjelkovikj, D. (2014): Optmization of using the non-urban ladn in the spatial planning in the Skopje region from aspects of decreasing the processes of its degradation. Phd. dissertation. University of Ss. Cyril and Methodius, Faculty of Forestry, Skopje. (Originally translated from: Трпчевска-Анѓелковиќ Д. (2014):Оптимизација на користење на вонурбаното земјиште во просторното планирање на Скопскиот регион од аспект на намалување на процесите на негова деградација, докторска дисертација. Универзитет “Кирил и Методиј”- Шумарски Факултет, Скопје).

[31] Not: Hicri 1310 (Miladi 1890) tarihli ve aslı Osmanlıca olan Kosova Vilayeti Salnamesi'nden ve bir Alman mühendisin plaından (Miladi 1890) yararlanılara Rumeli Türkleri Kültür ve Dayanışma Derneği Gençlik Komisyonu tarafından hazırlanmıştır. (Istanbul 2003) Hazirlayan: H. Yildirim Aganoglu, Grafik: Sibel Esen, Baski: Bircan Cakir

[32] Council of the European Union (2011) Territorial agenda of the European Union 2020: Towards an inclusive, smart and sustainable Europe of diverse regions. Agreed at the Informal Ministerial Meeting of Ministers responsible for Spatial Planning and Territorial Development, Gödöllő, Hungary 19 May 2011. http://ec.europa.eu/regional_policy/sources/policy/what/territorialcohesion/territorial_state_and_perspective_2011.pdf

[33] Odzaklieska H., Markoski B., Dimitrovska O., Milevski I. (2017) Basic methodological postulates for determining ecological footprint in Republic of Macedonia, Proceedings of the 5th Congress of the Ecologists of Macedonia, with international participation, (Ohrid, 19th—22nd October 2016), Special issues of the Macedonian Ecological Society 13, pp. 135-139, Skopje. ISBN-13 978-9989-648-37-3, Original scientific article, Available online at: www.mes.org.mk

ACTA GEOBALCANICA
5-2, 2019, pp. 75-84

# TOURISTS' PERCEPTION: THE CASE OF OHRID, MACEDONIA

DOI: *https://doi.org/10.18509/AGB.2019.09*
UDC: *338.48-2-052(497.771)*

**Biljana Petrevska**

*Faculty of Tourism and Business Logistics, Goce Delcev University - Stip, Macedonia*

corresponding author: biljana.petrevska@ugd.edu.mk

submitted: *28.03.2018*
accepted: *21.06.2018*
published: *18.01.2019*

**Abstract**

The aim of this study is to determine the factors that affect tourists on creating their images and perceptions while experiencing Ohrid, the most famous tourist destination in Macedonia. In this regard, the presence and affection of five factors was investigated: (i) Perception of place; (ii) Pull motives; (iii) Perception of safety; (iv) Type of experience; and (v) Fulfilled expectations. The analysis was based on face-to-face survey conducted with 500 tourists in June-August 2016. Generally, the findings indicate many suggestions and recommendations for tourism-policy makers. Towards the perception of the place, tourists found the sampled locations to be historic, legendary and religious places, which do not serve just as tourist places for sightseeing. As for the pull factors, the cultural heritage was perceived as attraction that brought tourists to the surveyed locations. Towards the perception of safety, Ohrid and Macedonia were perceived as fully safe and secure for tourism. Based on Cohen's (1979) classification of tourists, the results revealed that recreational tourists are the dominant group visiting Ohrid, followed by the existential, experiential, and experimental types of tourists, while the diversionary tourists were virtually absent. Finally, the surveyed tourists found highly fulfilled expectations evaluating Ohrid as destination worth visiting which gave a value to their money. The findings in this study may serve as a valuable starting point in creating new strategic approaches that may support tourism development in Ohrid and Macedonia.

Key words: tourist types, motives, Ohrid, tourism development.

## INTRODUCTION

The issue of perception by tourists and visitors is highly important since it enables tourism policy-makers to create new insights and tailor new strategic approaches that may increase the number of visits and night spent in the destination. While tourists' motivation is widely explored topic, the determining factors that affect tourists on creating images and perceptions has been somewhat unexplored research topics.

The primary objective of the study is to provide evidence on prevailing perceptions to create tourist image. This issue will be studied on the case of Ohrid, Macedonia. Ohrid represents a suitable test ground for investigating tourists' perception since it is the most famous tourist destination in Macedonia with 234,361 tourists and 830,333 overnights in 2016, this encompassed 27% of all arrivals and 34% of all overnight in Macedonia that year [19].

Additionally, to our best knowledge, no academic studies have dealt with this topic. Hence, this is the first attemt to identify the presence and affection of factors that affect tourists to create tourist image of Ohrid. The practical contribution of the paper lies in the recommendations that may serve as a valuable starting point in creating new strategic approaches that may support tourism development in Ohrid and Macedonia.

As for the organization of the paper, after the introduction, section two provides a snapshot on the literature review on tourist typology, as a background material. The applied methodology is presented in section three, while the findings and discussion are noted in section four. Section four presents the conclusion and recommendations, while the main limitation of the research and some future steps to be addressed, are noted in the last section of the paper.

## BACKGROUND MATERIAL

It is more than obvious that the tourist will create certain image about the destination depending on the preferences. Although may sound fragile, but the vast majority of today's tourists know exactly what they are looking for. Yet, they are very demanding and have complex, multi-layered desires and needs. Today's so called "postmodern tourists" have specific interests and individual motives which results in tailored made tourist products according to their particular preferences. They are often highly experienced in travelling and demand perfect tourism products rather than standardized ones.

The literature contains a large body of work discussing tourist roles in order to define their considerable variations. Mostly, the behavior is related to specific demographic and background characteristics emphasizing the life course as the leading component for investigating tourist role preferences. Yet, attention should be paid to a variety of social structures and processes, including psychological needs and life-course stage. Cohen [2] was one of the first sociologists who proposed a typology to conceptually clarify the term "tourist" by developing a four-fold typology. Few years later, Cohen [3] expended the list by suggesting a five-group classification of tourists, based on the type of experience they were seeking.

Pearce [14] identified specific behavior linking the evolutionary nature of tourist role preference and the psychological needs. Moreover, he developed 15 different tourist types which allowed creation of several measurement scales. In this respect, the Tourist Roles Preference Scale [22] presents a comprehensive classification of leisure tourists. Additional work resulted in adding two more tourist types to the tourist categorization [5]. A prior work that is related to the typology of Yiannakis and Gibson [22], is noted by Mo et al., [13] by designing International Tourist Role scale. Upon this scale, Keng and Cheng [9] and Jiang et al., [8] found that novelty seeking is related to choice of tourist role. Furthermore, a cluster analysis is offered by Ryan and Glendon [17] being derived from the Leisure Motivation Scale previously introduced by Beard and Ragheb [1].

Further on, researchers focused on exploring the experience of tourists as well as the importance of the tourist experience for tourists [23], along with classification of tourists according to the degree of novelty and familiarity sought [10].

## METHODOLOGY

In order to identify the main factors that affect tourists on creating images and perceptions while experiencing Ohrid, the research took qualitative and quantitative methods. The qualitative approach included review of literature and analysis of relevant publications. The quantitative approach covered data obtained from a face-to-face survey conducted among 500 tourists in June-August 2016. A questionnaire was developed for foreign and domestic tourists that visited Ohrid on two locations: the monastery of St. Naum (30 km from Ohrid near the border with Albania) and the church of Ss. Clement and Panteleimon at Plaosnik (located in the old part of the city center). The tourists were previously well informed about the survey's aim in order to avoid any attempt to manipulate the survey process and possibly bias the results. A schedule was established whereby data were collected during different days of the week and at different times of the day to maximize the chances of obtaining a representative sample. Prior to entering the field survey, the piloting was performed in order to check the validity of the questionnaire.

The survey instrument was a self-administered fixed-choice questionnaire. Respondents used a five point Likert scale (1=strongly disagree to 5=strongly agree) to judge the importance of each factor. The questions were structured in six section, as follows:

Section I contained nine questions referring general data of the respondents (gender, age, marital status, country of origin, education, type of visitor, type of holiday and frequency of visit);

Section II comprised of three questions defining the perception of place;

Section III comprised of three questions identifying the 'pull' motives;

Section IV encompassed three questions diagnosing tourist perception for safety;

Section V had a set of five questions defining tourist type (based on classification proposed by Cohen [2]); and

Section VI included three questions describing fulfilled expectations.

A total of 500 copies of the questionnaire were distributed, out of which 382 were deemed complete and usable, thus having response rate of 76.4%. The collected data were transferred to a common scorecard database in SPSS 24.0 in order to perform the statistical evaluation. Some descriptive statistics and nonparametric statistical tests were used for creating an initial tourist type for Ohrid among domestic and foreign tourists. In order to identify the possible relationship between the variables, the Chi-Square test ($\chi^2$) for independence was calculated.

## FINDINGS AND DISCUSSION

The findings are presented in a twofold manner. The first part discusses the general findings and discussion on the specific data. This means that each of the 26 questions that comprised the questionnaire was separately analyzed, whereas, the general data in accordance to the suggested categorization, while the specific data (17 questions) in accordance to a five-point Likert scale. The second part discusses findings based on cross-tabulations of general data versus specific data in order to discover a presence of association between the variables.

### Specific data findings

Table 1 presents the demographic attributes of respondents according to nine questions from the first section of the questionnaire (gender, age, marital status, country of origin, education, type of visitor, type of holiday and frequency of visit). It is noticeable a slight difference in favor of female respondents (54% vs. 45%). According to the age classification, most of the respondents (43%) belong to the group 30-49 years, followed by the elderly tourists of 50 years and over (32%), while the younger tourists (age 20-29) represent 25%.

With regards to the marital status, the vast majority of respondents are married (63%). As per country of origin, 57% of the surveyed tourists are domestic, while 43% are foreigners. According to the level of education, the dominant group of respondents (69%) hold university diploma, and the same percentage stands for being employed. Having in mind that the survey was conducted at two very famous and top-visited tourist location in Ohrid, which simultaneously represent religious places, the questionnaire contained a question on the type of visitor. Unsurprisingly, it was found that 71% are tourists, but surprisingly 19% of the respondents declared to be pilgrims, and even 10% replied to belong to the category “other” without specifying the meaning. Majority of the respondents are individual tourists who came by a self-organized visit (70%), vs. 30% who came on arranged tour by a travel agency. According to the frequency of visit, 45% of the respondents visited Ohrid more than five times so far. Yet, it is interesting to note that one/third (33%) of the visitors are newcomers meaning they visited Ohrid for the first time.

**Table 1.** Descriptive statistics on general data (∑=382)

| Item | % | | Item | % |
|---|---|---|---|---|
| Gender | | | Occupation status | |
| Male | 46.1 | | Student | 12.6 |
| Female | 53.9 | | Employed | 68.6 |
| Age | | | Unemployed | 6.3 |
| 20-29 | 24.6 | | Retired | 12.6 |
| 30-49 | 42.9 | | Type of visitor | |
| 50+ | 32.5 | | Pilgrim | 18.8 |
| Marital status | | | Tourist | 71.2 |
| Married | 62.3 | | Other | 9.9 |
| Single | 13.6 | | Type of holiday | |
| Divorced | 4.7 | | Individual (self-organized) | 69.6 |
| With partner | 15.7 | | Group (by travel agency) | 30.4 |
| Other | 3.7 | | Frequency of visit | |
| Country of origin | | | First time | 33.0 |
| Domestic tourist | 56.5 | | Second time | 8.4 |
| Foreign tourist | 43.5 | | 3-5 times | 13.6 |
| Education | | | More than 5 times | 45.0 |
| Elementary | 4.2 | | | |
| High | 27.2 | | | |
| Graduate | 68.6 | | | |

*Source*: Author’s calculations

The second section comprised of three questions defining the perception of place. The summarized findings are presented in Table 2. It may be concluded that tourists found the sampled locations to be historic, legendary and religious places, which do not serve just as tourist places for sightseeing.

This supports other complementary findings about the tourist types and pull motives. Section three of the questionnaire comprised of three questions identifying the 'pull' motives. Based on the experiential approach, we identified three factors that may attract tourists to visit Ohrid: cultural heritage, religion and sightseeing. After analyzing the results, it was found that the cultural heritage was perceived as attraction that brought tourists to the surveyed locations. This finding stands along with the second most tourist type being identified for Ohrid.

**Table 2.** Summarized findings on perception of place

| Question | Specific questions | % Strongly disagree | % Disagree | % Neutral | % Agree | % Strongly agree | SE Mean | Std. Deviation |
|---|---|---|---|---|---|---|---|---|
| Perception of place | Q1. This is a religious place | 1.6 | 6.3 | 12.6 | 34.6 | *45.0* | .04982 | .97366 |
| | Q2. This is just a tourist place for sightseeing | 14.1 | *30.9* | 19.9 | 18.3 | 16.8 | .06724 | 1.3141 |
| | Q3. This is a historic and legendary place | 2.1 | 1.6 | 11.0 | 29.8 | *55.5* | .04563 | .89177 |

*Source*: Author's calculations

Section three of the questionnaire comprised of three questions identifying the 'pull' motives. Based on the experiential approach, we identified three factors that may attract tourists to visit Ohrid: cultural heritage, religion and sightseeing. After analyzing the results, it was found that the cultural heritage was perceived as attraction that brought tourists to the surveyed locations. This finding stands along with the second most tourist type being identified for Ohrid.

There are many academic investigations that have identified political instability as a factor that may increase the perception of a risk at a destination [4], [6], [7], [11], [12], [15], [16], [18], [20] and [21]. In this line, the fourth section of the questionnaire encompassed three questions diagnosing tourist perception for safety. Ohrid (as tourist place) and Macedonia (as a country) were perceived as fully safe and secure for tourism. Even more, the total of 75% of the respondents disagree (39% strongly disagree and 36% disagree) that they hesitated to come because it appeared in the news that this is a country with security problems.

**Table 3.** Summarized results referring tourist typology

| Question | Specific questions | % Strongly disagree | % Disagree | % Neutral | % Agree | % Strongly agree | SE Mean | Std. Deviation |
|---|---|---|---|---|---|---|---|---|
| Type of tourist | Q10. I came here to enjoy myself (recreational tourist) | 1.0 | 11.5 | 22.5 | 26.7 | *38.2* | .05497 | 1.0744 |
| | Q11. I feel as if this visit has changed my life (diversionary tourist) | 11.5 | 21.5 | 33.0 | 21.5 | 12.6 | .06045 | 1.1814 |
| | Q12. I feel motivated and inspired here (experiential tourist) | 2.6 | 8.9 | 25.1 | 37.2 | 26.2 | .05235 | 1.0231 |
| | Q13. I came here to learn something about local people (experimental tourist) | 4.2 | 14.1 | 30.9 | 27.7 | 23.0 | .05715 | 1.1170 |
| | Q14. I came here to learn more about the lifestyle and culture of this place (existential tourist) | 4.7 | 7.3 | 26.7 | 31.4 | 29.8 | .05652 | 1.1045 |

*Source*: Author's calculations

Section five of the questionnaire had a set of five questions defining tourist type (based on classification proposed by Cohen [3]. Table 3 presents summarized findings. The results revealed that recreational tourists are by far the dominant group visiting Ohrid. Namely, 38.2% of the respondents strongly agree that came to enjoy themselves. Having in mind that this type of tourists put the emphasis on physical recreation, it is fully expectable that they will dominate due to the type of tourism Ohrid offers (sun, lake and leisure).

This is followed by the existential type of tourists whose main characteristic is that they want to become totally immerse in the lifestyle of the vacation destination. In this line, 29.8% responded that strongly agreed that they came to Ohrid to learn more about the culture of Ohrid. This finding confirms the already acknowledged fact that Ohrid is a cultural cradle and with the cultural heritage it possesses, attracts cultural tourists in large portion. A light step behind are the experiential type of tourists, whereas 26.2% of respondents strongly agree that they feel motivated and inspired at the place of survey. This is also expected finding since experiential tourists look for authentic experiences, and the sampled locations (St. Naum and Plaosnik) are really unique spots.

Experimental tourists, whose main desire is to be in contact with local people, responded that they visited Ohrid in order to learn something about local people (23%). Having in mind the rich history of the city, the specific artistic spirit along with numerous crafts (woodcarving, jewelry, pearl making, pottering, coppersmiths, shoemakers, etc.), still being performed in a traditional and original manner, attracts this type of tourists as well.

As the final tourist type, the research investigated whether Ohrid attracts diversionary tourists. It was found that they were virtually absent due to insignificant presence of only 12.6%. This type of tourists seek way of forgetting their everyday life at home.

The last, sixth section of the questionnaire included three questions describing fulfilled expectations. The respondents found highly fulfilled expectations, thus evaluating Ohrid as a destination worth visiting which gave a value to their money.

Namely, 72% strongly agreed that the sampled location was worth visiting and if adding the responses “agreed” (22%), it may be concluded that 94% actually were delighted and enchanted of Ohrid. Furthermore, 42% strongly agreed and 29% agreed, meaning that 71% of the respondents got more than expected. Finally, 61% strongly agreed and 27% agreed, or all together 88% of respondents would like to come back again and visit Ohrid. This supports the previous fact where it was noted that 45% visited Ohrid form more than five times. Simultaneously, it gives good prospects that the newcomers would come again.

**Cross-tabulations**

This part discusses the main findings upon the cross-tabulations of general data versus specific data (Table 4). It illustrates the association between categorical variables i.e. whether the variables are mutually independent or correlated. Due to fact that the calculated p-value is lower than the standard significance level ($\alpha = 0.05$), we reject the null hypothesis. Therefore, we conclude that there is enough evidence to suggest that there is statistically significant association between the variables. Yet, no inferences about the causation can be provided.

**Table 4.** Summarized results of the cross-tabulations general vs. specific data

| General data | Question | $\chi^2$ (p-value) |
|---|---|---|
| Gender | Q4. I came here… cultural heritage attractions | .012 |
| | Q6. I came here just for sightseeing | .054 |
| | Q15. This place is worth visiting | .012 |
| | Q16. I’ve got more than expected from this place | .004 |
| | Q17. I would like to visit this place again | .001 |
| Age | Q1. This is a religious place | .001 |
| | Q2. This is just a tourist place for sightseeing | .000 |
| | Q3. This is a historic and legendary place | .000 |
| | Q4.I came here… cultural heritage attractions | .000 |
| | Q5. I came here for religious reasons | .015 |
| | Q6. I came here just for sightseeing | .041 |
| | Q7. The place is fully safe and secure for tourism | .000 |
| | Q8. The country is fully safe and secure for tourism | .000 |
| | Q9. I hesitated to come … security problems | .015 |
| | Q10. Recreational tourist | .005 |
| | Q11. Diversionary tourist | .000 |
| | Q12. Experiential tourist | .000 |
| | Q13. Experimental tourist | .013 |
| | Q15. This place is worth visiting | .001 |
| | Q17. I would like to visit this place again | .000 |
| Marital status | Q1. This is a religious place | .009 |
| | Q2. This is just a tourist place for sightseeing | .000 |
| | Q3. This is a historic and legendary place | .000 |
| | Q4. I came here… cultural heritage attractions | .003 |
| | Q5. I came here for religious reasons | .000 |
| | Q6. I came here just for sightseeing | .002 |
| | Q7. The place is fully safe and secure for tourism | .004 |
| | Q8. The country is fully safe and secure for tourism | .000 |
| | Q9. I hesitated to come … security problems | .000 |

| | | |
|---|---|---|
| | Q10. Recreational tourist | .000 |
| | Q11. Diversionary tourist | .000 |
| | Q12. Experiential tourist | .000 |
| | Q13. Experimental tourist | .000 |
| | Q14. Existential tourist | .002 |
| | Q15. This place is worth visiting | .000 |
| | Q17. I would like to visit this place again | .000 |
| Country | Q1. This is a religious place | .026 |
| | Q5. I came here for religious reasons | .000 |
| | Q6. I came here just for sightseeing | .000 |
| | Q9. I hesitated to come … security problems | .000 |
| | Q10. Recreational tourist | .000 |
| | Q11. Diversionary tourist | .022 |
| | Q12. Experiential tourist | .000 |
| | Q13. Experimental tourist | .000 |
| | Q14. Existential tourist | .000 |
| | Q16. I've got more than expected from this place | .043 |
| | Q17. I would like to visit this place again | .001 |
| Education | Q2. This is just a tourist place for sightseeing | .021 |
| | Q3. This is a historic and legendary place | .021 |
| | Q4. I came here… cultural heritage attractions | .004 |
| | Q7. The place is fully safe and secure for tourism | .010 |
| | Q10. Recreational tourist | .000 |
| | Q11. Diversionary tourist | .048 |
| | Q12. Experiential tourist | .003 |
| Status | Q1. This is a religious place | .001 |
| | Q2. This is just a tourist place for sightseeing | .000 |
| | Q3. This is a historic and legendary place | .000 |
| | Q4. I came here… cultural heritage attractions | .004 |
| | Q5. I came here for religious reasons | .001 |
| | Q6. I came here just for sightseeing | .040 |
| | Q7. The place is fully safe and secure for tourism | .001 |
| | Q10. Recreational tourist | .042 |
| | Q11. Diversionary tourist | .000 |
| | Q12. Experiential tourist | .000 |
| | Q13. Experimental tourist | .038 |
| | Q14. Existential tourist | .004 |
| | Q15.This place is worth visiting | .004 |
| | Q16.I've got more than expected from this place | .003 |
| Type of visitor | Q1. This is a religious place | .000 |
| | Q2. This is just a tourist place for sightseeing | .005 |
| | Q3. This is a historic and legendary place | .009 |
| | Q4. I came here… cultural heritage attractions | .000 |
| | Q5. I came here for religious reasons | .000 |
| | Q6. I came here just for sightseeing | .000 |
| | Q7. The place is fully safe and secure for tourism | .001 |
| | Q8. The country is fully safe and secure for tourism | .001 |
| | Q10. Recreational tourist | .000 |
| | Q11. Diversionary tourist | .000 |
| | Q12. Experiential tourist | .000 |
| | Q13. Experimental tourist | .042 |
| | Q14. Existential tourist | .001 |
| | Q15. This place is worth visiting | .002 |
| | Q17. I would like to visit this place again | .000 |
| Holiday | Q1. This is a religious place | .035 |
| | Q2. This is just a tourist place for sightseeing | .044 |
| | Q5. I came here for religious reasons | .000 |
| | Q6. I came here just for sightseeing | .016 |
| | Q9. I hesitated to come … security problems | .022 |
| | Q10. Recreational tourist | .000 |

| | | |
|---|---|---|
| | Q12. Experiential tourist | .011 |
| | Q13. Experimental tourist | .004 |
| | Q14. Existential tourist | .031 |
| | Q16. I've got more than expected from this place | .019 |
| Frequency | Q1. This is a religious place | .000 |
| | Q3. This is a historic and legendary place | .001 |
| | Q4. I came here… cultural heritage attractions | .007 |
| | Q5. I came here for religious reasons | .000 |
| | Q6. I came here just for sightseeing | .000 |
| | Q7. The place is fully safe and secure for tourism | .000 |
| | Q8. The country is fully safe and secure for tourism | .000 |
| | Q9. I hesitated to come … security problems | .003 |
| | Q10. Recreational tourist | .000 |
| | Q11. Diversionary tourist | .001 |
| | Q12. Experiential tourist | .000 |
| | Q13. Experimental tourist | .031 |
| | Q14. Existential tourist | .000 |
| | Q15. This place is worth visiting | .000 |
| | Q17. I would like to visit this place again | .000 |

*Source*: Author's calculations

Note: Only data with a significance $p<0.05$ are presented

Based upon the calculations presented in Table 4, we find enough evidence to suggest that there is association between the nine variables of general data (gender, age, marital status, country of origin, education, occupational status, type of visitor, type of holiday, and frequency of visit) and some specific data. In this line, statistically significant association is found as follows:

- With regards to the gender, both male, and female tourists not equally prefer the same pull motives and fulfilled expectations;
- As per age, the association is found almost in all investigated issues. This means that the age makes difference, since all three categories (younger tourists between 20-29 years, mature tourists between 30-49 years, and older tourists being over 50 years) responded differently. There are only two exceptions noted. Namely, there is no correlation between age and the existential type of tourist (Q14) as well as between age and the return to place (Q16);
- Presence of association is assessed between marital status and all, but one questioned issue (Q16). So, whether the tourist is married, single, divorced, live with a partner, or even replied as 'other', makes a difference to all investigated issues, with the exception of 'getting more than expected from the place'. This means that the marital status is not correlated only to this specific aspect defining the returning to the place;
- Being domestic or a foreign tourist (as per country of origin) makes statistically significant relations to perceiving the sampled location as a religious place, being attracted by religious or
- sightseeing motives, tourist typology, and return to the destination. However being domestic or a foreign tourist does not make a difference to the perception for safety;
- Education (tourists with elementary, high school or faculty education) is related to seven out of seventeen investigated queries. The type of education is correlated with the majority of tourist types (recreational, diversionary and experiential) along with the motives that create a perception of place. The education is associated to the cultural heritage as a pull motive that attracts tourists to visit the destination, the same as the destination's perception for safety;
- Occupational status is correlated with all the specific investigated issues, except for the perception on the safety of the country (Q8 and Q9). So, students, employed, unemployed and retired tourists equally perceive Macedonia as safe tourist destination;
- The type of visitor is generally related to all the specific issues. The exception is noted with regards the 'hesitation to come because it appears in the news that Macedonia has security problems' (Q9) and 'got more than expected' (Q16). So, whether respondents declared as pilgrims, tourists or 'other', makes no difference only in these two queries;
- Visiting Ohrid individually (self-organized) or in a group (by travel agency) is related to perceiving Ohrid as religious and tourist place, but not as historic and legendary place. The type of holiday makes no difference when it comes to the safety perception of Ohrid (place) and Macedonia (country), the same as in the case of creating an image for fulfilled expectations; and

- Frequency of visit i.e. visiting Ohrid for the first time, second time, 3-5 times, or more than five times, has an influence when creating a tourist image for Ohrid. Generally, there is an association between the variables, with just only one exception. According to the frequency of visit, tourists equally find to get more than expected.

**Table 5.** Summarized results on presence of independency, general vs. specific data

| General data | Specific data (grouped queries) |
|---|---|
| Gender | Perception of place (Q1-Q3) |
| | Pull motives (Q4-Q6) |
| | Perception for safety (Q7-Q9) |
| | Tourist type (Q10-Q14) |
| Country of origin | Perception of place (Q1-Q3) |
| | Perception for safety (Q7-Q9) |
| Education | Pull motives (Q4-Q6) |
| | Perception for safety (Q7-Q9) |
| | Return to place (Q15-Q17) |
| Occupational status | Perception for safety (Q7-Q9) |
| Type of holiday | Perception for safety (Q7-Q9) |
| | Return to place (Q15-Q17) |

*Source*: Author's calculations
Note: Summarized results for data with a significance p>0.05

More general conclusions from the cross tabulations are presented in Table 5 referring to independency of the variables. It is noticeable that gender is by far the most independent variable, followed by education, country of origin, type of holiday and occupational status. Namely, as presented in Table 5, it can be concluded that 'perception for safety' is a strongly independent factor when creating tourism image. On the other side, it was found that:

- Gender matters when it comes to the fulfilled expectations (return to place);
- Country of origin matters when it comes to the pull motives, tourist type and fulfilled expectations;
- Type of education matters when it comes to the perception of place and tourist type;
- Occupational status matters when it comes to perception of place, pull motives, tourist type and return to place; and
- Type of holiday matters when it comes to perception of place, pull motives and tourist type.

Furthermore, based on the established correlation patterns, it can be summarized that the variables like: age, marital status, type of visitor and frequency are statistically dependent categories. This means that tourism policy makers should have in mind to make tourism segmentation particularly taking into consideration these criteria when creating tourism policy and development strategy.

## CONCLUSION AND RECOMMENDATIONS

Based upon the field work and findings, the study recommends some future actions in the line of creating new strategic approaches that may support tourism development in Ohrid. First, efforts should be made to make tourism fully recognizable and to improve the current marketing strategy. The focus should be on promotion, mainly through the introduction of new innovative approaches. The second strategic measure recommended for improving tourism competitiveness is to strengthen the coordination between the central and local governments, in addition to other tourism players from the private sector. The objectives and aims delineated by the tourism development plans and programs must be fully implemented, regardless of the level of implementation. The expectations of all tourism suppliers must conform to the expectations of tourists and travelers who visit Ohrid. By combining the insights from earlier works, the study identified and explored the presence of five factors, upon which tourists create images and perceptions for Ohrid. It was found that Ohrid is perceived as historic, legendary and religious place and not just as a plane tourist destination, whereas the cultural heritage is the main pull factor for attracting tourists. Towards the perception for safety, both, Ohrid (as tourist place) and Macedonia (as a country), were perceived as fully safe and secure for tourism. According to the type of experience, the recreational tourists are by far the most present. Being described as destination worth visiting which gave a value to their money, tourists found to have highly fulfilled expectations from Ohrid as a destination.

Furthermore, it was found that gender is by far the most independent variable meaning that generally both male, and female tourists equally create tourism image of Ohrid. This is followed by education, whereas it was found that it is irrelevant where the tourist has elementary, high school or faculty diploma. What is especially interesting is that both domestic and foreign tourists in general perceive the same Ohrid as a destination when it comes to its perception of place and safety.

Likewise, variables like: age, marital status, type of visitor and frequency, are totally statistically dependent, pointing to be used as segmentation criteria when defining tourism development strategy. So, younger tourists create different perception for Ohrid, compared to mature and older tourists. This is also the case if tourists replied as married, single, divorced, live with a partner, or even ‘other’. If respondents declared as pilgrims, tourists or ‘other’, makes difference to creating a tourist image of Ohrid. According to the frequency of visit, tourists does not equally experience Ohrid. Yet, due to fact that the calculated values of the nonparametric tests assess only association between the variables without providing inferences about the causation, it is up to tourism experts to interpret them accordingly.

## LIMITATIONS AND FUTURE WORK

The research was limited by several factors that can also serve as productive starting points for future work. First, it employed a relatively small set of indicators and could be enhanced by the addition of additional significant indicators to better assess tourists’ perception. Because data was collected using only a questionnaire survey, the research may also suffer from the common method variance effect. As the research was characterized by a relatively small sample size, future work could focus on increasing the number of respondents and other aspects of investigation. Finally, instead of using one model, future research could employ multiple models and theories relevant to tourism imaging.

## REFERENCES

[1] Beard, J. G. & Ragheb, M. G. (1983). Measuring leisure motivation. Journal of leisure research, 15, 219-228.

[2] Cohen, E. (1972). Towards a sociology of international tourism. Social Research, 39, 164-182.

[3] Cohen, E. (1979). A phenomenology of tourist experience. Sociology 13(2), 179-201.

[4] Gartner, W. & Shen, J. (1992). The Impact of Tiananmen Square on China’s Tourism Image. Journal of Travel Research, 30(4), 47-52.

[5] Gibson, H. & Yiannakis, A. (2002). Tourist roles: Needs and the lifecourse. Annals of Tourism Research, 29(2), 358-383.

[6] Hollier, R. (1991). Conflict in the Gulf. Tourism Management, 12, 2-4.

[7] Ioannides, D. & Apostolopoulos, Y. (1999). Political Instability, War and Tourism in Cyprus: Effects, Management and Prospects for Recovery. Journal of Travel Research, 38(1), 51-56.

[8] Jiang, J., Havitz, M. & O’Brien, R. (2000). Validating the International Tourist Role Scale. Annals of Tourism Research, 27, 964-981.

[9] Keng, K. & Cheng, J. (1999). Determining Tourist Role Typologies: An Exploratory Study of Singapore Vacationers. Journal of Travel Research, 37(4), 382-391.

[10] Lepp, A. & Gibson, H. (2003). Tourist roles, perceived risk and international tourism. Annals of Tourism Research, 30(3), 606-624.

[11] Mansfeld, Y. (1996). Wars, Tourism and the “Middle East” Factor. In Tourism, Crime and International Security Issues (A. Pizam and Y. Mansfeld, eds.), pp. 265-278. New York: Wiley.

[12] Mansfeld, Y. (1999). Cycles of War, Terror and Peace: Determinants and Management of Crisis and Recovery of the Israeli Tourism Industry. Journal of Travel Research, 38(1), 30-36.

[13] Mo, C., Howard, D. R. & Havitz, M. E. (1992). Testing an international tourist role typology. Annals of Tourism Research, 20, 319-335.

[14] Pearce, P. (1982). The social psychology of tourist behaviour. New York: Pergamon.

[15] Richter, L. (1992). Political Instability and Tourism in the Third World. In Tourism and the Less Developed Countries, (D. Harrison, ed.), pp. 35-46. New York: Wiley.

[16] Richter, L. (1999). After Political Turmoil: The Lessons of Rebuilding Tourism in Three Asian Countries. Journal of Travel Research, 38(1), 41-45.

[17] Ryan, C. & Glendon, I. (1998). Application of leisure motivation scale to tourism. Annals of Tourism Research, 25(1), 169-184.

[18] Seddighi, H., Nuttall, M. & Theocharous, A. (2001). Does Cultural Background of Tourists Influence the Destination Choice? An Empirical Study with Special Reference to Political Instability. Tourism Management, 22, 181-191.

[19] State Statistical Office of the Republic of Macedonia. (2017). Statistical Yearbook for 2016, Skopje.

[20] Teye, V. (1986). Liberation Wars and Tourism Development in Africa: The Case of Zambia. Annals of Tourism Research, 13, 589-608.

[21] Wall, G. (1996). Terrorism and Tourism: An Overview and an Irish Example. In Tourism, Crime and International Security Issues, (A. Pizam and Y. Mansfeld, eds.), pp. 143-158. New York: Wiley.

[22] Yiannakis, A. & Gibson, H. (1992). Roles Tourist Play. Annals of Tourism Research, 19, 287-303.

[23] Yfantidou, G., Costa, G. & Michalopoulos, M. (2008). Tourist roles, gender and age in Greece: a study of tourists in Greece. International Journal of Sport Management Recreation & Tourism, 1, 14-30.

ACTA GEOBALCANICA
5-2, 2019, pp. 85-92

# ORIGIN AND EFFECTS OF ANTHROPOGENIC FLASH FLOODS ON RIVERS OF HOLY CROSS MTS. REGION (POLAND) IN 20th c.

DOI: *https://doi.org/10.18509/AGB.2019.10*
UDC: *551.432.46:556.512]:627.5(438)*

**Tomasz Kalicki, Paweł Przepióra, Piotr Kusztal**

*Institute of Geography, Jan Kochanowski University in Kielce, Poland*

corresponding author: tomaszkalicki@ymail.com

submitted: *24.04.2018*
accepted: *01.07.2018*
published: *18.01.2019*

**Abstract**
In the 20th c., after the disappearance of the system of small retention (number of artificial ponds, channels etc.) due to economic changes, on the rivers (Kamionka, Czarna Konecka) appeared events previously unknown during the whole Holocene. There are catastrophic flash floods caused by hydrotechnical damage. Geomorphological effects of these floods exceed many times the effects of secular processes.

Keywords: Holy Cross Mts., river valleys, human impact, flash floods

## INTRODUCTION

The research area is located in the northern part of the Holy Cross Mountain region (central Poland) (Fig. 1). This region is characterized by large industrialization (mining and metallurgy), which started in the Middle Ages (the Old Polish and later the Central Industrial District) [1], [2], [3], [4].

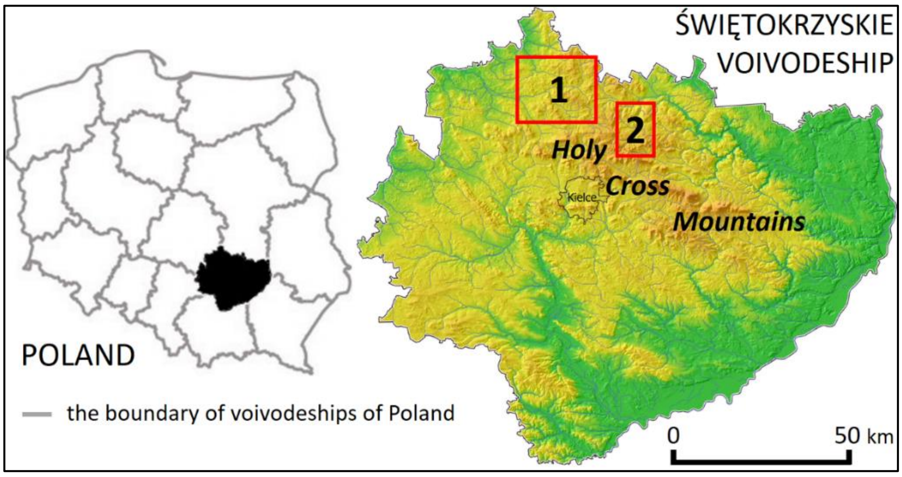



**Figure 1**. Location of study basins[1]
1 – Czarna Konecka river basin, 2 – Kamionka river basin

The iron ore resource base and water power allowed for the development of many smaller towns, where forges, smelters, and water wheel mills were functioning. This has resulted in the creation of numerous ponds, riverbed regulations and the construction of channels in order to provide sufficient energy. At the turn of the 19th and 20th century, the forges activity, and in the middle of the 20th century water mills were finally stopped. Some ponds were drained and their infrastructure destroyed, while others changed their functions to retention and recreation [5].

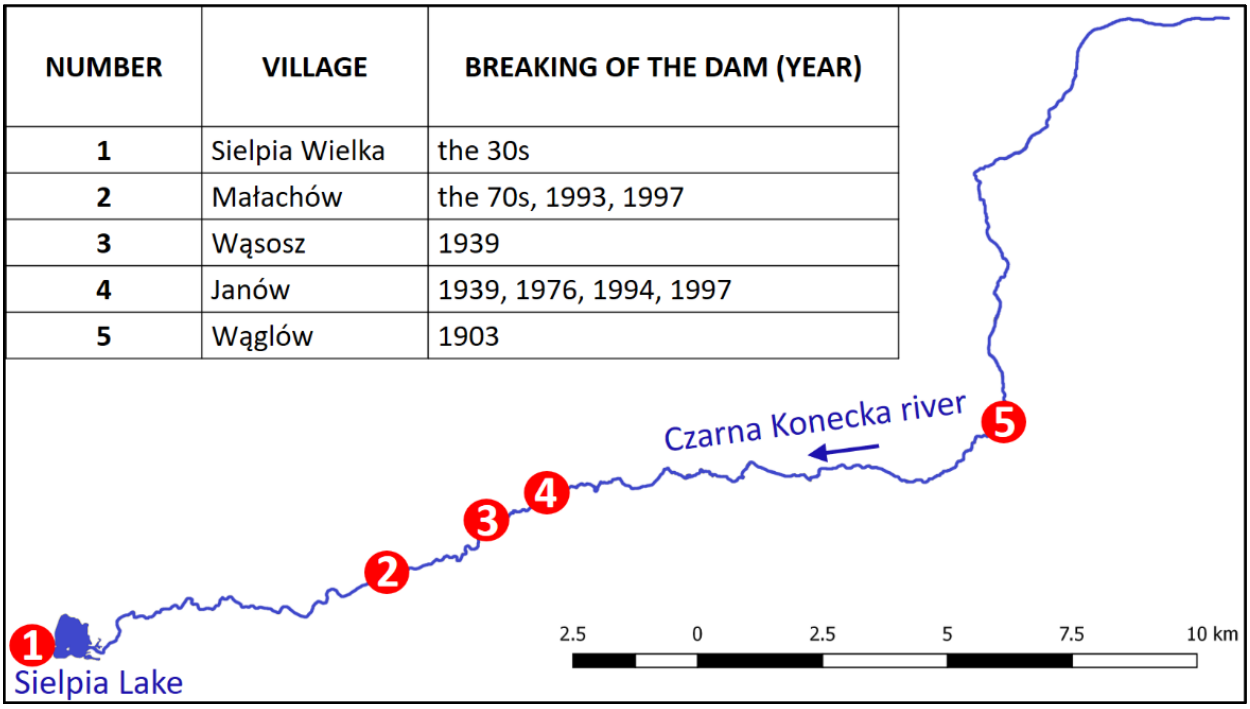
[1] Digital Elevation Model (Archives UJK)

## METHODS

The research was interdisciplinary. Informations from archival sources (cartographic, historical) were verified in the field. Grain size of very coarse alluvia of bars was investigated in the field by the Wolman's method [6], where the size of clasts situated on the measurement lines is determined every fixed number of meters or centimeters. TL date [7] was conducted in the Scientific-Didactic Laboratory of the Institute of Geography of Jan Kochanowski University in Kielce.

## RESULTS

While the anthropogenic small retention system from the Middle Ages had a beneficial effect on the regulation and rate of water circulation in the catchments, in the 20th century the deteriorating technical infrastructure was conducive to the catastrophic events formation not previously occurred in the whole Holocene. In the flood periods, break in the shafts and dams, resulting in rapid drainage of the ponds lead to create the flash floods downstream from the reservoirs. This kind of event took place at Czarna Konecka river in 1903 (Wąglów), the 30s (Sielpia Wielka), 1939 (Wąsosz, Janów), the 70s (Małachów), 1976 (Janów), 1993 (Małachów), 1994 (Janów), 1997 (Janów, Małachów) (Fig. 2) and at Kamionka river in 1939 (Rejów) and 1974 (Suchedniów) [8].



| NUMBER | VILLAGE | BREAKING OF THE DAM (YEAR) |
|---|---|---|
| 1 | Sielpia Wielka | the 30s |
| 2 | Małachów | the 70s, 1993, 1997 |
| 3 | Wąsosz | 1939 |
| 4 | Janów | 1939, 1976, 1994, 1997 |
| 5 | Wąglów | 1903 |



**Figure 2**. Anthropogenic flash floods in the Upper Czarna Konecka river valley caused by break of artificial dams [8]

The geomorphological effects of these flash floods were very large, even bigger than effects of secular processes. In Kamionka valley downstream of Suchedniów reservoir, where in 1974 took place a break of the dam just after finished the construction work, in regulated riverbed accumulate large concrete elements of dam and embankments and even a 1 m in diameter sandstone boulder (Fig. 3) [9]. In Czarna Konecka valley at Wąsosz Stara Wieś, few hundred meters downstream of the broken dam, was accumulated very coarse channel sediments (pebbles, gravels and sands) mixed with the slags as a remain of the forge activity (Fig. 4). The thickness of this cut-fill within the upper floodplain reaches 2 m, while on the lower step of it is about 30 cm thick layer of these sediments covered older alluvium [10]. Alluvial bodies or layers of such coarse alluvia are not known from the older cut-fills of the Holocene floodplain [11]. Repeated catastrophic discharges and increased erosion after hydrotechnical failures caused incising and transformation of the riverbed (Fig. 5), floodplain (Fig. 6) and silting of the reservoir at Sielpia Wielka (Fig. 2, 7, 8) [8].

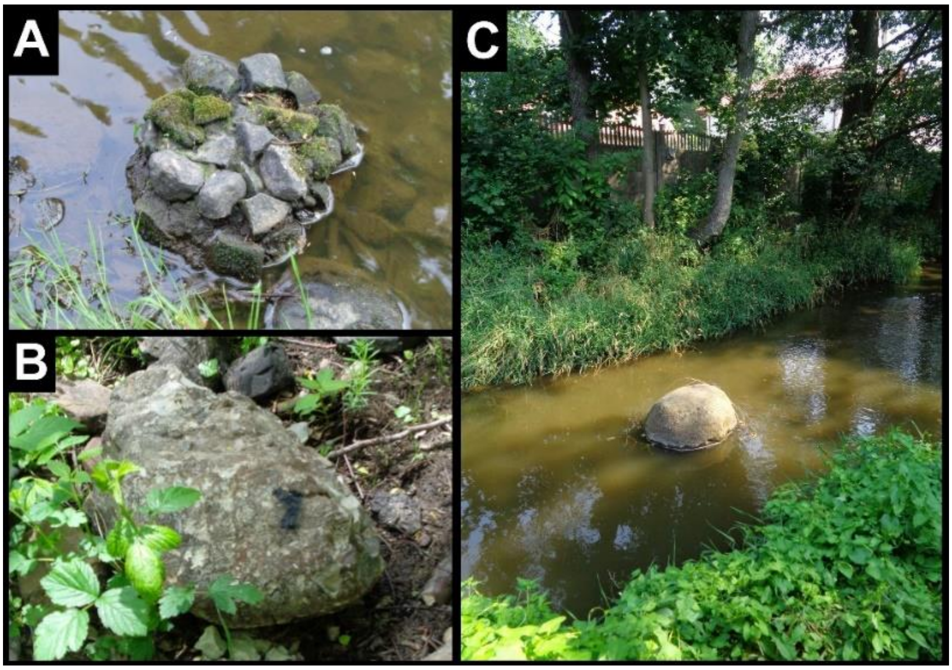



**Figure 3**. Traces of the flood from 1974 in the Kamionka riverbed downstream of the Suchedniów Lake dam: concrete fragments of a broken dam (A, B) and sandstone pebble with diameter about 1 m (C) transported by a flood wave (photo 2014) [8]

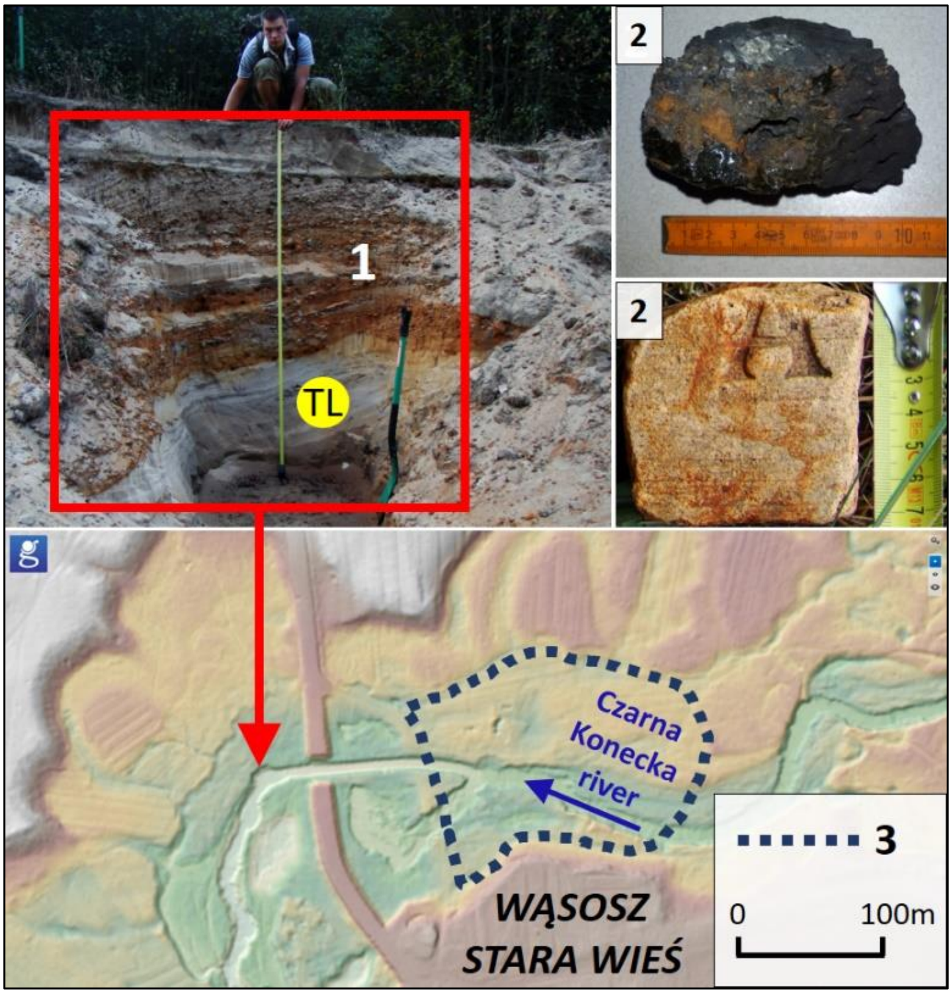



**Figure 4**. Cut-fill of very coarse deposits of flash flood (1) with artifacts (2) on flood plain from 20$^{th}$ c. (TL – present-day) downstream of the former pond (3) at Wąsosz Stara Wieś[2] (photo 2016) [8]

[2] http://mapy.geoportal.gov.pl/imap/

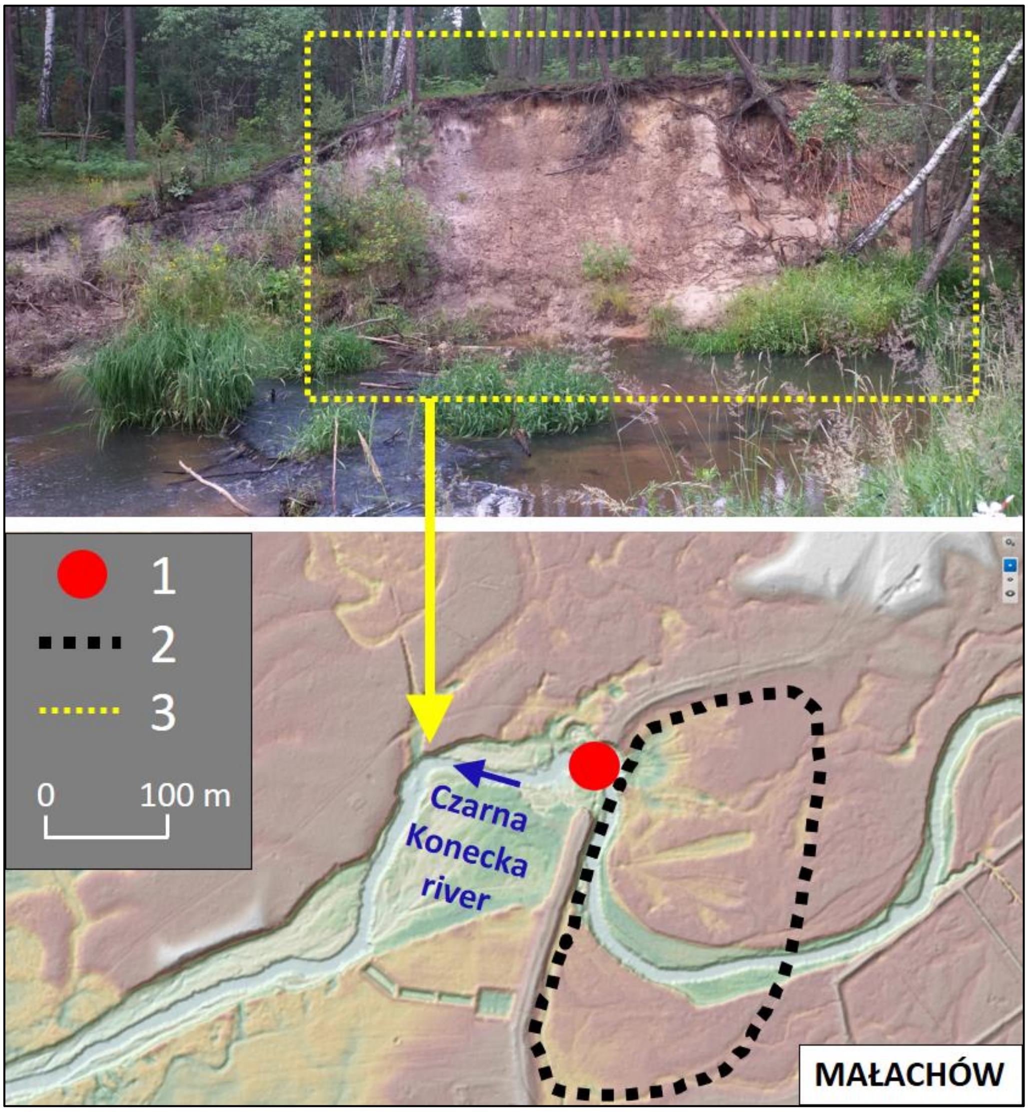



**Figure 5**. Upper Czarna Konecka river valley at Małachów[2] (photo 2017) [8]
1 – destroyed dam, 2 – former pond, 3 – erosional river bank cut by anthropogenic flash flood and hydrological changes after the dam break and pond disappearance

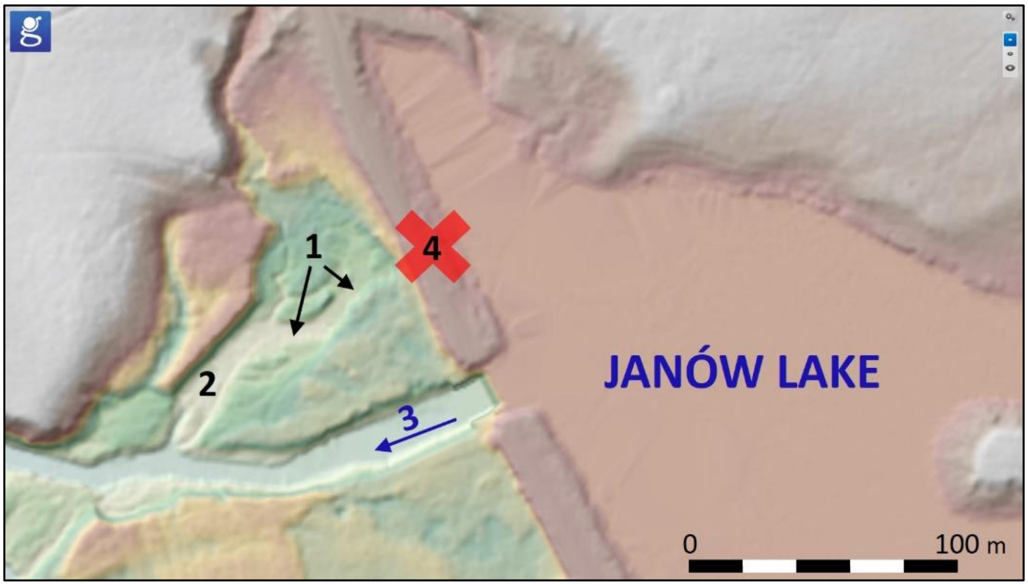



**Figure 6**. Erosional channels (1, 2) on upper Czarna Konecka flood plain resulting from dam break and rapid drainage of pond at Janów[2] (pers. communications Paweł Kusztal) [8]
1 – flood's channel, 2 – transformed valley of unnamed tributary, 3 – present-day Czarna Konecka river, 4 – place of breaking the dam in 1994

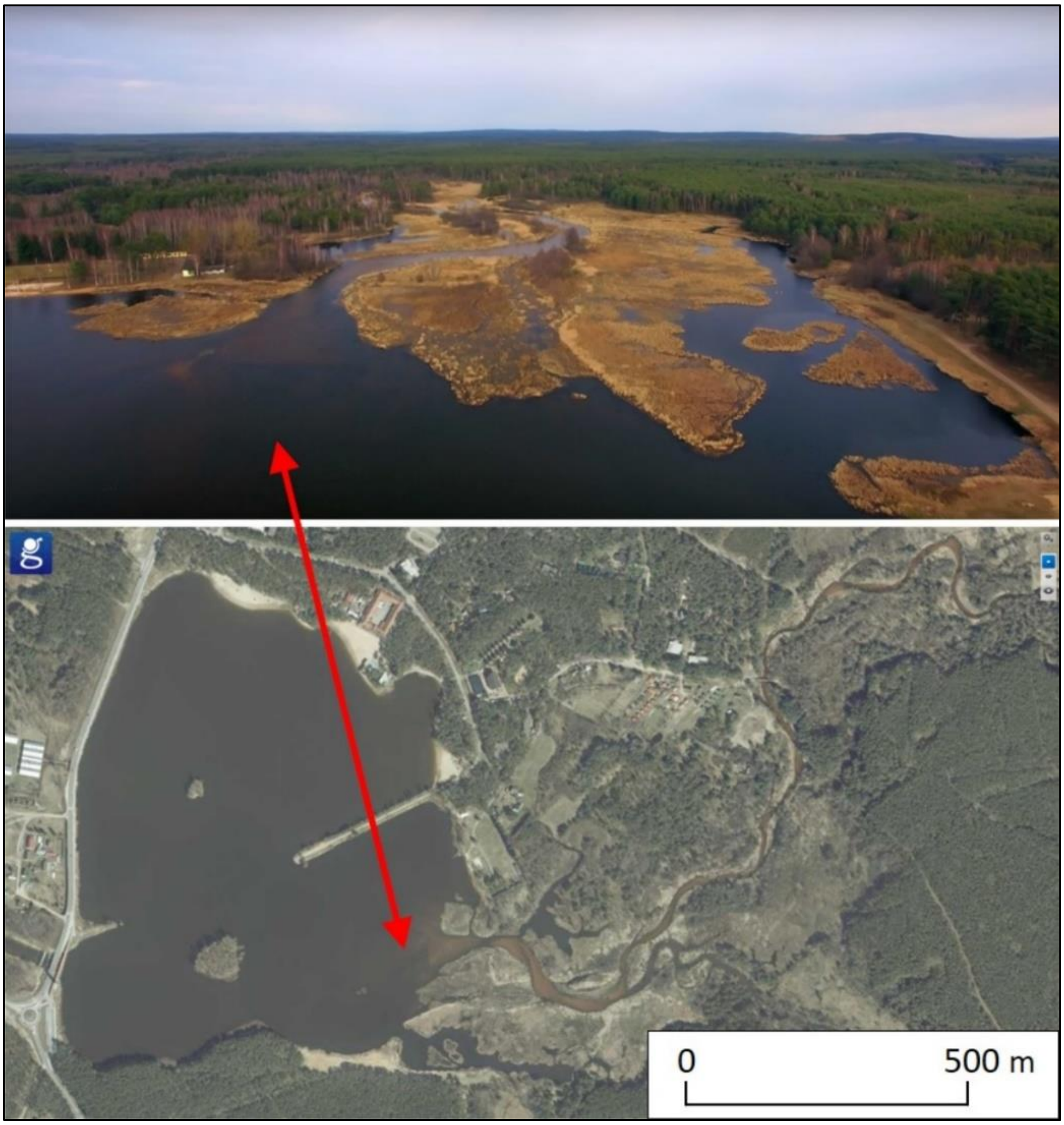



**Figure 7.** Delta in the mouth of upper Czarna Konecka river to artificial pond at Sielpia Wielka[2, 3] (photo Ł. Wasik 2016) [8]. Estimated depth of the lake in this part is 0.5-0.8 m [12]

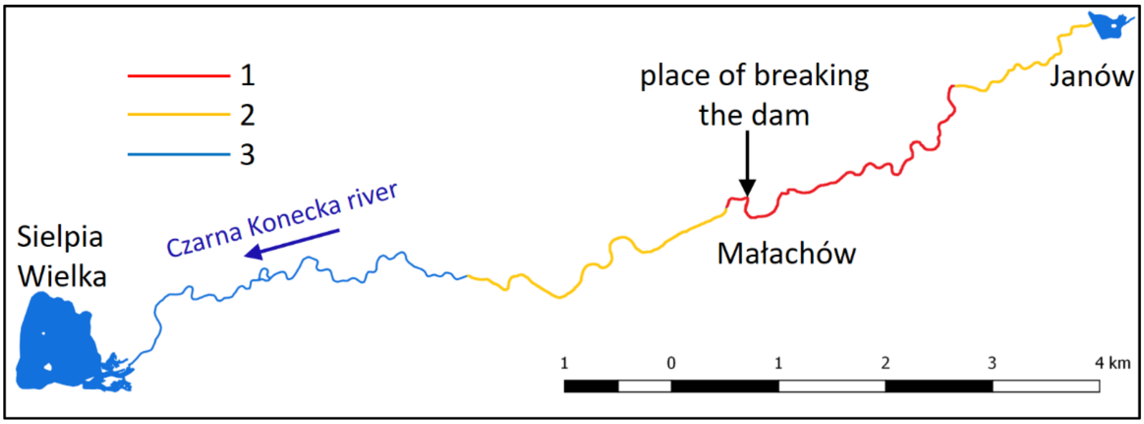



**Figure 8.** Upper Czarna Konecka river between the reservoirs at Janów and Sielpia Wielka.
Channel sections with intensive incision in 1993-1995 (1) [5] and in 1995-2017 (1, 2) and accumulation (3) as a result of the failure of the former dam at Małachów (1993), [8]
(prepared on the basis of channel mapping)

[3] https://www.youtube.com/watch?v=uwyf3N7go-Q&index=33&list=UUqclsFfwvWjip-wxRMNUA2A

Water management of Suchedniów reservoir (Kamionka river) also cause anthropogenic floods (e.g. 2010), that influence a texture of the floodplain alluvia. Grain size analysis of gravel bars on about 300 m section downstream of the pond indicated the fining sequence of deposits along with an increase distance from the dam (Fig. 9). The finest sediments accumulated on the river bend, where the water speeds is decreasing during water discharge from the lake [9].

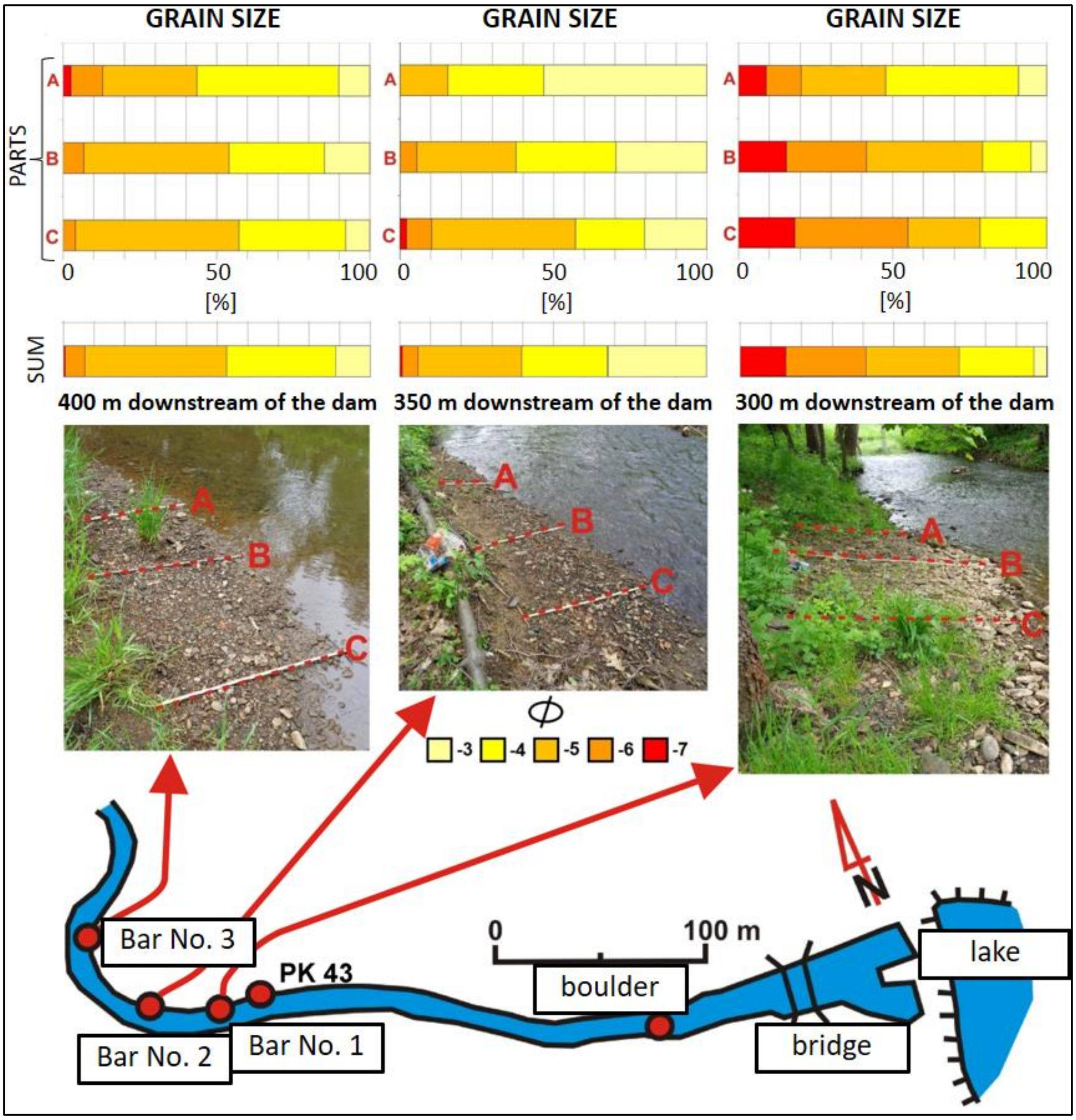



**Figure 9**. Gravely bars in Kamionka riverbed downstream of the Suchedniów Lake, grain size analyzed based on planimetric method with the location of major objects [8]

## DISCUSSION

At the turn of the 19th and 20th century, the forges activity finally stopped, same as the water mills in the middle of the 20th c.. Some of the ponds were drained and their infrastructure was destroyed. Function of other ponds was changed to flood-control and recreation. The anthropogenic small retention constructed since the Middle Age had a beneficial effect on the regulation and speed of water circulation in the catchment. In the 20th c. the technical infrastructure decay was conducive to forming a catastrophic flash floods that was not present in the whole Holocene (no evidence of such events in alluvia and morphology). During the rainy floods there was a break in the shafts and dams that led to rapid drainage of the water reservoir and forming flash floods in the valley downstream of them. This kind of events had occurred many times on the Czarna Konecka and Kamionka river. The geomorphological effects of these floods were very big, surpassing many times the effects of secular processes. These high energy flows determined the cut-fill accumulation of very coarse-grained channel sediments in the sections downstream of the broken dams in those two valleys. Not rebuilt dams in the Czarna Konecka river led to a very intensive incision of the riverbed, resulting in confined meanders (Fig. 10) and fix of the single channel pattern [11]. Also flood-control management on the reservoirs cause anthropogenic floods, for example in Suchedniów Lake in 2010. Those floods forms the coarse grain size of present-day bars and alluvia fining with distance from the dam.

**Figure 10**. Confined meander of upper Czarna Konecka river (photo 2015)

## CONCLUSIONS

Construction and the subsequent collapse of anthropogenic small retention system led to create catastrophic floods in the valleys of the Holy Cross Mts. region, which had not previously occurred in the whole Holocene. They have transformed the morphology and alluvia of the flood plains and riverbeds.

## ACKNOWLEDGMENTS

The study was funded by Jan Kochanowski University project BS 612 480.

## REFERENCES

[1] Bielenin K. Starożytne górnictwo i hutnictwo żelaza w Górach Świętokrzyskich, Wydanie drugie, poszerzone i poprawione, Kieleckie Towarzystwo Naukowe, pp. 1-267, 1993.

[2] Fajkosz A. (eds.) Wczoraj i dziś stąporkowskich odlewni, CzZG, ZP Kielce, Stąporków, pp. 1-99, 1978.

[3] Nowak S. (eds.) Almanach Świętokrzyski, Stąporków i okolice z historią industrialną w tle, Oficyna Wydawnicza Edward Mitek, Warszawa-Bydgoszcz-Kielce, vol. 2, pp. 1-439, 2017.

[4] Piasta S. Leksykon Suchedniowa, Towarzystwo Przyjaciół Suchedniowa, Kielce, pp. 1-496, 2012.

[5] Kalicki T., Przepióra P., Kusztal P. & Nowak M. Anthropogenic flash floods on rivers of Holy Cross Mts. region in 20th c. – origin and effects, 3rd Disaster Risk Reduction Conference, Warsaw, 2017, pp. 49.

[6] Wolman M.G. A metod of sampling coarse river – bed material, Am. Geophys. Union Trans., 35, 6, pp. 951–956, 1954.

[7] Pazdur A., Bluszcz A., Stankowski W. & Starkel L. (eds) Geochronologia Górnego Czwartorzędu w Polsce w świetle datowania radiowęglowego i luminescencyjnego, Wind. Wojewoda J., Wrocław, pp. 1-287, 1999.

[8] Kalicki T., Przepióra P. & Kusztal P. Anthropogenic flash floods on rivers of Holy Cross Mts. region in 20th c. – origin and effects, Prace i Studia Geograficzne, in print.

[9] Przepióra P. Naturalne i historyczne zmiany zlewni Kamionki (Płaskowyż Suchedniowski) w subatlantyku, Typescript of PhD. degree, Archives UJK, Kielce, pp. 1-140, 2017.

[10] Nowak M.M. Budowa geologiczna i rzeźba doliny Czarnej Koneckiej w rejonie Wąsosza Starej Wsi, Typescript of Msc. degree, Archives UJK, Kielce, pp. 1-103, 2017.

[11] Kalicki T., Frączek M., Przepióra P., Kusztal P., Kłusakiewicz E. & Malęga E. Overview of the Late Quaternary geomorphological and geoarchaeological research in the Holy Cross Mts. region, Quaternary Research, in print.

[12] Grzyb H., Zięba B., Piotrowicz A. & Pachołowiecka-Grzyb H. Ekspertyza wraz z koncepcją zabezpieczenia dna rzeki Czarnej Malenieckiej przed erozją i zamulaniem zbiornika w Sielpi (część opisowo-zestawieniowa), Na zlec. WZMiUW w Kielcach, Kielce, pp. 1-33, 1995.

ACTA GEOBALCANICA
5-2, 2019, pp. 93-101

# ALTERATION OF THE MORPHO-HYDROLOGICAL CONDITIONS OF THE AQUATIC COMPLEXES ADJACENT TO THE SF. GHEORGHE BRANCH (DANUBE DELTA) AS A RESULT OF THE HYDROTECHNICAL WORKS

DOI: *https://doi.org/10.18509/AGB.2019.11*
UDC: *556.54(498)(282.243.7.05)*

**Cristian Trifanov[1], Alin Mihu-Pintilie[2, 3], Marian Mierlă[1]**

*[1]Danube Delta National Institute for Research and Development, Informational System and Geomatics Department, Romania*
*[2]Alexandru Ioan Cuza University of Iași, Faculty of Geography and Geology, Department of Geography, Romania*
*[3]Alexandru Ioan Cuza University of Iasi, Interdisciplinary Research Department – Field Science, Romania*

corresponding author: cristian.trifanov@ddni.ro

submitted: *10.04.2018*
accepted: *03.06.2018*
published: *18.01.2019*

## Abstract
The hydrotechnical works on Sf. Gheorghe arm in Danube Delta was done by Institute for Research and Planning for Water Management. The work was part of the framework scheme for the Dobrogea hydrographic area and was nominated in the investment plan of the National Water Council. The regularization works, started in 1988, consists in the rectification of the main meanders of the arm in the following sectors: lvancea, Dranov, Dunavăț and Murighiol. The total length of the rectification is 15 km and the shortening of the natural course is 32 km. These works impose changes in the balance of the hydrological regime on the main course, along the meanders and on the channels connecting the arm waters and the aquatic complexes within the delta. By altering the fractal dimension of the arm, fluviatile processes are intensified and have irremediable long-term repercussions. This leads to the eutrophication of lakes in the aquatic complexes by low water intake, then clogging of the channels and, also, of the lakes resulting in diminishing / changing the habitats. As clear evidence are these two channels: Ivancea and Erenciuc north (completely clogged). Now, other 4 channels are threatened, which already show very low depths at the confluence with the Sf. Gheorghe arm. This is an exhaustive study of the current situation of the meanders of the Sf. Gheorghe arm from the morphological point of view and the fragile longitudinal and lateral connectivity through morphometric analysis methods using geomatics techniques. The foundation of this study will be based on existing literature, field data, historical and current data, in collaboration with other institutes and universities capable of providing important data such as sediments, hydro-technical works, etc.

Keywords: Danube Delta, wetlands, geomatics, underwater morphology

## INTRODUCTION
This ongoing study represents the main author's PhD thesis. It is mainly a technical study that aims to enrich the hydrological data for the Sf. Gheorghe arm of the Danube Delta in respect to riverbed mapping of the meanders and their connection to the main river flow and the adjacent channels. Its results will help other research domains to benefit of the maps and database to estimate the environment development based on the actual state of the riverbed. The main objective of the study is to map all six meanders using high resolution hydrological equipment and to evaluate the evolution of the riverbed correlated with the historical data.

The Danube Delta is situated in the north-western sector of the Black Sea basin, in a mobile region of the terrestrial crust (the Predobrudjan Depression). Its limits are: 44°46'00"N (Periteasca), 45°30'00"N (South of Sasik Lake), 28°40'24"E (Ceatalul Chilia), 29°40'50"E (East of the Chilia secondary delta). As for its surface of 5,600 km$^2$, the Danube Delta, together with the floodplain sector between Ceatalul Ismail and Galaţi City, represent the most important terminal plain of any European river (except the Volga and Kuban deltas on the territory of C.I.S.). The Ukrainian part, about one-fifth of the total Delta area, covers 125,000 ha of which 75,000 ha is land and 50,000 ha are water [1-6].

The Sf. Gheorghe arm is the oldest arm of the Danube Delta, which currently carries about 30% of the volume of water and sediments of the Danube. It derives from the Tulcea branch on the right-hand side of the bifurcation at kilometer 108.8, with mostly a single and meandering riverbed, which was naturally preserved until 1988 [7-9]. The year in which a collective effort to regulate the watercourse began so that the six meanders of the arm were subjected to a "adjustment" necessary for the protection of the shore, strongly eroded, south of the mouth of the arm and also necessary for the economic activities to the detriment of: the hydrological and sedimentological equilibrium of the adjacent aquatic complexes; the sedimentation regime at the mouths of the channels and the mouth of the arm; the reed quality; the habitats; the water surfaces; the landscape quality [10-19].


**Figure 1.** a. Location of the Danube Delta (SE Romania); b. The Sf. Gheorghe bifurcation

Over time, the study of this aspect, namely: the impact of the redistribution of flows to the adjacent aquatic complexes following the hydrological regulations, was in depth studied immediately after the completion of the hydrotechnical works, then the studies focus on the main course of the arm, on the evolution of the sediments and the way in which it influences the mouth of the river and the evolution of the coastal area. Thus, the situation of the meanders and their silting has been left aside. The subject is of interest to the scientific environment not only for the enrichment of the poor hydrological data base on this Danube arm and for the behavioral studies of migratory fish, especially for sturgeon species, for the specificity of habitats and ecosystems that are dependent on certain physicochemical parameters of the water, impact studies and water flow improvement through hydrotechnical works. At the same time, this study responds to the requirements of national and international environmental and sustainable development policies and guidelines such as: Danube Delta Biosphere Reserve Management Plan; Water Framework Directive; European Union Strategy for Danube Region and Master Plan – Support for sustainable development in Danube Delta Biosphere Reserve.

## STATE OF THE ART

Regularization of Sf. Gheorghe's arm downstream from Mahmudia town was carried out on the basis of project 1274 elaborated by the Institute for Research and Development for Water Management at the command of Water Administration Office No. 1574. The work was part of the framework scheme for the Dobrogea hydrographic area and was nominated in the investment plan of the National Water Council. The regularization works consist of the rectification of the main meanders of the St. George arm in the Ivancea, Dranov, Dunavăț and Murighiol sectors. The total length of the rectification is 15 km and the shortening of the natural course of 32 km$^2$. The project proposes to provide a clear picture of the morpho-hydrographic dynamics of the current and historical Sf. Gheorghe meanders using GIS and remote sensing methods, field data collected by single and multi-beam interferometer, ADCP and topography for a holistic understanding of how the water circulation to the aquatic complexes adjacent to the Sf. Gheorghe arm and the support capacity of its riverbed for migratory fish habitats of national and international interest.

The study of the behavior of sturgeon species migrating upstream on the Danube only on the Sf. Gheorghe arm is incipient and there are many gaps in the knowledge of this relic species. It is considered very important to identify the breeding and resting places of the individuals and this is possible only by mapping the riverbed of Sf. Gheorghe arm. According to recent studies, the sturgeons prefer to approach the deepest and largest current, and for rest they use the excavations (pits) of the riverbed with oblong shapes with a steep upstream slope beyond witch the currents are diminished or perhaps nonexistent. The identification of these excavations is necessary to know the behavior of these species, not only for a better prediction of the route in the Danube but also for the knowledge of the locations of the telemetry stations in order to monitor the captured and marked individuals. A similar problem is represented by mackerel populations. It is desirable to monitor through telemetry techniques and for this purpose it is necessary to map the riverbed of the Sf. Gheorghe arm. It is worth mentioning that these two large and main migratory fish species use only Sf. Gheorghe arm to reach the spawning located further upstream on the river.


**Figure 2.** Hydrometrical profiles at the Sf. Gheorghe bifurcation:
a. Tulcea Arm; b. Sulina Arm; c. Sf. Gheorghe Arm.

Another problem is the morphological aspect of the arm as a result of the regularization works, namely the silting of the meanders. Besides the landscape preservation importance and the value of surface water bodies, it is the contribution of fresh and oxygenated water to adjacent aquatic complexes. Note that access (channels) to aquatic complexes lie on the edges of the meanders and the rectification directly influences the equilibrium of water distribution flows. This leads to the eutrophication of lakes in the aquatic complexes by the low intake of fresh oxygenated water, then the clogging of the lakes and the diminution of the habitats. Clear evidence is the two channels Ivancea and Erenciuc North: completely silted. At present the Perivolovca, Uzlina, Dranov and Dunavat canals are threatened, which already show very low depths at the mouth.

## METHODS AND TECHNIQUES

It is proposed an exhaustive study of the current situation of the Sfântu Gheorghe meanders from the morphological point of view of and fragile longitudinal and lateral connectivity through morphometric analysis using GIS techniques and remote sensing. The foundation of this study will be based on existing literature, field data, historical and current data, in collaboration with other institutes capable of providing important data such as sediment, hydro-technical works, etc. [20-28].
Throughout the period of PhD studies, field data will be collected at well-established time intervals in normal and special hydrological conditions to identify the evolution and trends of the riverbed on the main course of the arm and meanders. Historical and current bathymetric data will be used that will

help to correlate the erosion and silting indicators in critical areas with hydrological events. At the same time, remote sensing techniques will be used on satellite and aerial images to extract historical information on the aspect of islands and bank configuration and their correlation with hydrological events [29], [30]. To start with, there is a need to know how much water the Sf. Gheorghe arm takes from the Tulcea arm. Various measurements were done before by different scientists and the variations between the measurements are dependent of the water level regime and this measurement was done at the average water level quota. The flow distribution situation is very interesting now: Sulina 40% and Sf. Gheorghe 60%. The bifurcation is presented in the Figure 1. and represents the starting point of the studied riverbed: St. Gheorghe. Using the flow and velocity measurement equipment at the bifurcation of the Tulcea arm in Sulina and Sf. Gheorghe, hydrometric profiles were performed and the measured flows are centralized in Table 1. The positions of these profiles and the overall distribution of the currents are represented in Figure 2.

**Table 1.** The flow distribution at the Sf. Gheorghe bifurcation

| Arm name | Measured Flow (mc/s) | Flow with correction | Distribution (%) |
|---|---|---|---|
| Tulcea | 3,674 | 3,674 | - |
| Sulina | 1,425 | 1,457.5 | 39.67 |
| Sf. Gheorghe | 2,184 | 2,216.5 | 60.33 |

Comparing these values to the historical values from 1992, after the hydrotechnical interventions one can notice a major change in the proportions of flow distribution on the two arms, from 63% on the Sulina arm and 37% on the Sf. Gheorghe arm to 40% on the arm Sulina and 60% on the Sf. Gheorghe branch. However, it can be noticed that the current distribution of the flows due to the hydro-morphological dynamics reached the same values as in the period 1928-1929 (41% on the Sulina arm and 59% on the Sf. Gheorghe branch).

Data collection started in summer 2017 and it begun at the most downstream meander on Sf. Gheorghe arm: Ivancea meander. The expedition was possible using the Danube Delta National Institute for Research infrastructure, namely ANTIPA as headquarters boat and the data collection using NAUTILUS 500, a small survey boat. The data collection process is an aggregate of different equipment for specific tasks. In order to properly map any riverbed, information such as water level quota, water velocity and discharge is critical for the final output. Beside the collection of the already mentioned data, an impetuous task is to develop the topographic support network. Since the GSM/DGPS signal is scarce throughout the whole area, determining fixed topographical points in key locations along the measured area is critical when using RTK positioning corrections of the multibeam interferometer.

The multibeam interferometer is a complex aggregate of different sensors such as: the transducer, as the emitter and the receiver of the sounding data; SVS (Sound Velocity Sensor) that applies corrections of the water sound speed, MRU (Motion Reference Unit) that applies corrections regarding the boat movement on all the three axes, Heading that applies corrections concerning the survey direction of the boat, Double frequency GPS (Global Positioning System) in RTK mode (Real Time Kinematic) for accurate positioning of the soundings and also time synchronization. All these sensors are integrated into a RTA console (Real Time Applience) that transmits the data through UTP (Unshielded Twisted Pair) connection to a computer that runs ES3 together with Hypack software, where all this data is integrated and carefully calibrated. As soon as the equipment was installed on the survey boat, calibrated and checked, the survey started and the mapping routing paths of the Ivancea meander can be seen in Figure 3. The Figure 4 is displaying the data acquisition process, where the surveyor can monitor all the aspects of the measurement such as boat direction, soundings cover, the aspect of the profile, the different messages of the system, etc. This facilitates the data collection process to be as accurate as possible. As a result of the completion of the bathymetric data collection campaign, the general picture of the Ivancea meander riverbed aspect is shown in the final matrix (Fig. 5).

## RESULTS AND DISCUSSION

At first glance, a typical characteristic of meandering morphology is observed on the color palette. The river bed scours occur at a range of scales and settings and are most pronounced at river bends and channel confluences. The depths are surprisingly high considering the low hydraulic slope and the proximity (~ 10 Km) of the mouth of arm into the Black Sea. However, the erosion processes are strong in the upstream part of the meander, where it erodes in the left bank of the island created by the hydraulic regulation, thus generating very high currents and depths (-24 m). But this is normal and to be expected for such natural processes. Further downstream on the meander, there is a submerged island in the convex part of the meander (close to the right bank) that acts as a barrier, thus protecting the former depths of the main course behind it, and also behaving as a precursor to the visible fairway that almost extends downstream, to the confluence with the main flow of the arm. The average depths are -12 m, in the upstream area where the erosion is strong in the meander, the depth is -24 m, the fairway that starts from the middle of the meander towards downstream has an average depth of -15 m, and downstream, at the confluence, where both discharges are rejoined, there is a deepening of the fairway that reaches up to -19 m.

**Figure 3.** Boat routes for covering the whole survey area

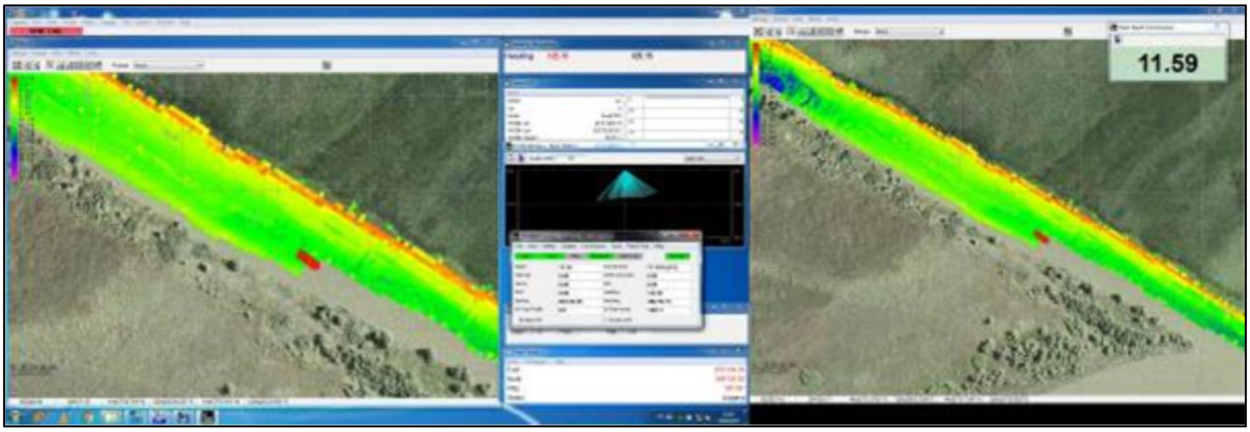



**Figure 4.** Print screen of the data collection process with the multi-beam interferometer

Data processing is done with in Hypack software package. This is modular software that allows to be used concurrently with other analysis processes. The MBMax module is used to process multibeam bathymetric data, allowing editing of collected points in the field by editing the anomalies, etc. The data can be viewed and edited as color-coded wireframe, dots, mesh and variable number of soundings (depending on the computational resources). Some examples can be seen in Figures 6, 7 and 8. The anomalies can be observed the in the collected data, namely those lines that rise or fall abruptly. These are referred in the literature as "spikes" and are usual abnormalities in any bathymetric data collection process. These occur due to a misinterpretation of the transducer induced by many variables: boat shocks due to engine speed, high velocity changes in water, suspended particle matter, fish banks, positioning error (changing the horizon of a one or more satellites), loss of TRK communication with the base GPS, etc. These abnormalities can be erased to a limited extent automatically by applying a depth filter and to a large extent manually. The software allows the user to view cloud points in multiple ways so that editing this data is as easy as possible. The data processing is a very meticulous task with trial and error methodologies, and the results are expert judgment because in many cases the user needs to interpret data where bathymetric values are missing or are displaying errors.

**Figure 5.** Matrix of raw bathymetric data collection

**Figure 6.** The sample location of the bathymetric data – downstream of the main course confluence with the meander

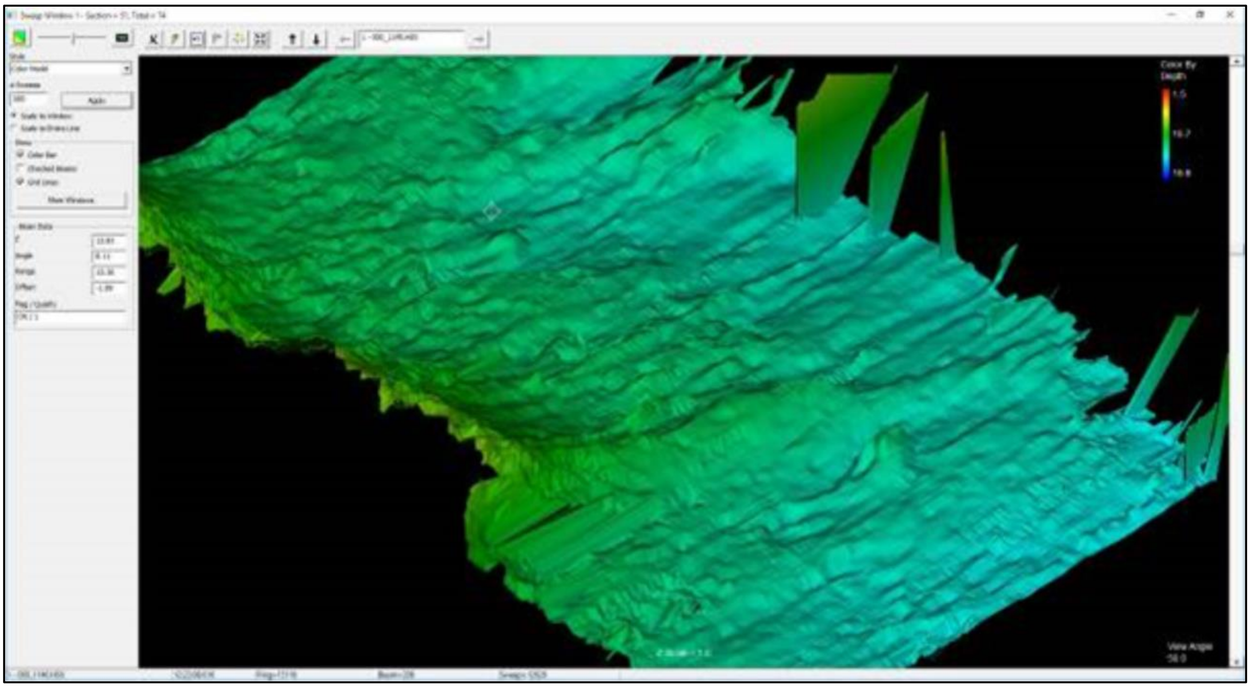


**Figure 7.** Representing raw data as a mash model with a gradual colour palette according to the depths in the bathymetric data collection matrix

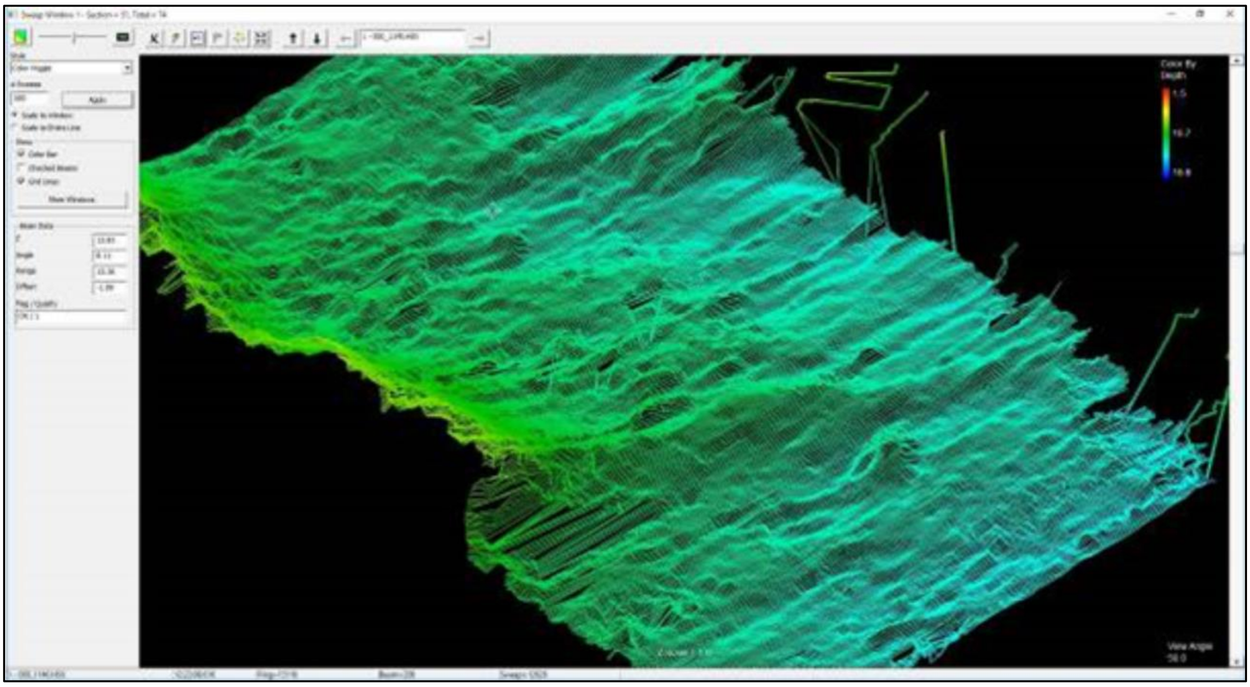


**Figure 8.** Representing raw data as wireframe soundings with the gradual colour palette according to depths in the bathymetric data collection matrix

## CONCLUSIONS

The studies conducted by the Institute for Hydraulic Research on the rectification of the Sf. Gheorghe arm have predicted, as it was normal, that the execution of the meanders regularization as well as the diverting channel to the south of the arm will probably lead to an increase of the flow with 4 – 6.5% at average flow rates. The researches mainly focused on the knowledge of the drainage system and the sandy river deposits, in the new conditions, due to the regularization of the meanders. At the same time, on the changes in the sedimentary balance of the coastal zone and consequently in the evolution of the erosion processes of the beaches under the influence of the flow regime is changes. The hydrological situations in which the measurement campaigns were conducted were quite different from one year to the next. Liquid and solid flow data refers to the situation on the measurement day and any generalization must be taken into account by applying this coefficient.

Thus, between 1988 and 1993, the highest liquid flow of the Sf. Gheorghe arm, measured in September 1989, was 1,034 $m^3/s$. In 1990, also in September, were measured the lowest water levels, flow rates and liquid and solid flows of the Danube in the last 40 years; this year the average liquid flow on Sf. Gheorghe arm was 502 $m^3/s$. A similar situation occurred in August 1992, when the average liquid flow was 567 $m^3/s$. In the autumn of 1991 and in August 1993, liquid flows had higher values: 886 $m^3/s$ and 829 $m^3/s$.

The liquid flow distribution factors of the Tulcea branch between the Sulina and Sf. Gheorghe arms, under small and average flow rates recorded on the days when the historical measurements were made, are the following: 1993 (average flow): Tulcea M34 = 3,072 $m^3/s$, Sulina = 0.54*Q Tulcea, Sf. Gheorghe = 0.46*Q Tulcea; 1992 (low flow): Tulcea M34 = 1,210 $m^3/s$, Sulina = 0.63*Q Tulcea; Sf. Gheorghe = 0.37*Q Tulcea; 1990 (low-medium flow): Q Tulcea M34 = 1,800 $m^3/s$, Sulina = 0.54*Q Tulcea, Sf. Gheorghe = 0.46*Q Tulcea. By comparing these distributions with the previous situation, namely: period 1928 – 1929: Sulina = 0.41*Q Tulcea, Sf. Gheorghe = 0.59*Q Tulcea; period 1958 – 1960: Sulina = 0.45*Q Tulcea, Sf. Gheorghe = 0.55*Q Tulcea.

There is a change in the distribution of water between the Tulcea branch and the Sulina and Sf. Gheorghe arms. This change occurred between 1970 and 1980 and is probably due to the constructive additions to the consolidation of the bifurcation point on Sf. Gheorghe, which partly deviates the current to Sulina arm, as well as the natural tendency of silting and advancing towards N of the right concave bank (southern) of the Tulcea and Sf. Gheorghe arms right at the bifurcation, which determines the direction of a larger part of the flow to the Sulina branch, especially during the periods of small waters. By comparing all this historical data with the recent measurements, it is clearly that the flow has increased on Sf. Gheorghe arm and the distribution is almost the same as prior to the hydraulic implementations on the Sf. Gheorghe arm. This remains to be further investigated within this PhD thesis. The problem, far from being elucidated, remains a very interesting objective for further research, especially for high liquid flow and flood conditions, these situations being also those that play the most important role in geo- and hydro- dynamic modeling of the area.

## REFERENCES

[1] Romanescu G., Pascal M., Mihu-Pintilie A., Stoleriu C.C., Sandu I. & Moisii, M. Water Quality Analysis in Wetlands Freshwater: Common Floodplain of Jijia-Prut Rivers, Revista de chimie, Romania, vol. 68(3), pp 553-561, 2017.

[1] Romanescu G. Delta Dunării. Studiu morfohidrografic, Ed. Corson, Romania, 1996.

[2] Romanescu G. Morpho-hydrographical evolution of the Danube Delta - Aquatic surfaces and inner lands, Ed. PIM, Romania, 2003.

[3] Romanescu G. Complexul lagunar Razim-Sinoie. Studiu morfohidrografic, Ed. Universitatii „Alexandru Ioan Cuza" of Iasi, Romania, 2006.

[4] Romanescu G. Geoarchaeology of the ancient and medieval Danube Delta: Modeling environmental and historical changes. A review, Quaternary International, vol. 293, pp 231-244, 2013.

[5] Romanescu G. The catchment area of the Milesian colony of Histria, within the Razim-Sinoie lagoon complex (Romania): hydro-geomorphologic, economic and geopolitical implications, Area, UK, vol. 46(3), pp 320-327, 2014.

[6] Romanescu G. Tourist exploitation of archaeological sites in the Danube Delta Biosphere Reserve area (Romania), International Journal of Conservation Science, Romania, vol. 7(3), pp 683-690, 2016.

[7] Romanescu G. & Cojocaru I. Hydrogeological considerations on the western sector of the Danube Delta – a case study for the Caraorman and Saraturile fluvial-marine levees (with similarities for the Letea levee), Environmental Engineering and Management Journal, Romania, vol. 9(6), pp 795-806, 2010.

[8] Romanescu G. Alluvial Transport Processes and the Impact of Anthropogenic Intervention on the Romanian Littoral of the Danube delta, Ocean & Coastal Management, vol. 73, pp 31-43, 2013.

[9] Romanescu G. & Stoleriu C. Anthropogenic interventions and hydrological-risk phenomena in the fluvial-maritime delta of the Danube (Romania), Ocean & Coastal Management, vol. 102, pp 123-130, 2014.

[10] Adopo K.L., Romanescu G., N'Guessan A.I. & Stoleriu C. Relations between man and nature and environmental dynamics at the mouth of the Komoé river, Grand-Bassam (Ivory Coast), Carpathian Journal of Earth and Environmental Sciences, Romania, vol. 9(4), pp 137-148, 2014.

[11] Adopo K.L., N'Guessan M.Y., Sandu A.V., Romanescu G. & Sandu I.G. The spatial distribution and characterization of sediments and the bottom morphology of the hydroelectric lake in Ayamé 2 (Ivory Coast), International Journal of Conservation Science, Romania, vol. 7(2), pp 567-578, 2016.

[12] Allenbach K., Garonna I., Herold C., Monioudi I., Giuliani G., Lehmann A. & Velegrakis A.F. Black Sea beaches vulnerability to sea level rise, Environmental Science & Policy, vol. 46, pp 95-109, 2014.

[13] Eilersten R.S. & Hansen L. Morphology of river bed scours on a delta plain revealed by interferometric sonar, Geomorphology, vol. 94, pp 58-68, 2008.

[14] Feodot I., Project Nr. PN 09 26 04 08, Morpho-fractal analysis of the hydro-morphological dynamics of the Danube Delta's main branches - Complex analysis of the macroforms - the meanders and islands of the Sf. Gheorghe arm, 2015.

[15] Geological Center and Marine Geo-ecology, Scientific research No.2 - The study of the sedimentological and geological complex of the environmental changes in the Danube Delta and the adjacent coastal zone determined by the hydrotechnical regulations on Sf. Gheorghe arm for the identification of protection measures of deltaic and coastal ecosystems, 1995.

[16] Keremedchiev S. & Valchev N. Morphodynamic analysis of the coastal zone in the area of St. George sub-delta (Danube Delta) and the Sakalin Island (NW Black Sea), Comptes Rendues de l'Academie Bulgare des Sciences, vol. 61(8), pp 1037-1046, 2008.

[17] Matenco L., Munteanu I., Borgh M., Stanica A., Tilita M., Lericolais G., Dinu C. & Oaie G. The interplay between tectonics, sediment dynamics and gatways evolution in the Danube system from the Pannonian Basin to the western Black sea, Science of the Total Environment, vol. 543, pp 807-827, 2015.

[18] Provansal M., Vella C. & Sabatier F. Sedimentary imputs and mobility of deltaic coasts during the Holocene, Oceanis, France, vol. 29, pp 209-238, 2006.

[19] Vespremeanu-Stroe A., Zăinescu F., Preoteasa L., Tătui F., Rotaru S., Morhange C., Stoica M., Hanganu F., Timar-Gabor A., Cârdan I. & Piotrowska N. Holocene evolution of the Danube delta: an integral reconstuction and an revised chronology, Marine Geology, vol. 388, pp 38-61, 2017.

[20] Mierla M., Romanescu G., Nichersu I. & Grigoras I. Hydrological risk map for the Danube delta - a case study of floods within the fluvial delta, IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol. 8, pp 98-104, 2015.

[21] Radevski I. & Gorin S. Floodplain analysis for different return periods of river Vardar in Tikvesh valley (Republic of Macedonia), Carpathian Journal of Earth and Environmental Sciences, Romania, vol. 12, pp 179-187, 2017.

[22] Romanescu G. Morphology and Dynamics of the Danube Delta Littoral between the Sulina and Sfântu Gheorghe River Mouths (Romania), Revista Pontica, Romania, vol. 43, pp 515-531, 2010.

[23] Romanescu G., Sandu I., Stoleriu C. & Sandu I.G. Water Resources in Romania and Their Quality in the Main Lacustrine Basins, Revista de Chimie (Bucharest), Romania, vol. 65(3), pp 344-349, 2014.

[24] Romanescu G. Geomorfologie litorala, Ed. Transversal, Romania, 2015.

[25] Romanescu G., Bounegru O., Stoleriu C., Mihu-Pintilie A., Nicu C., Enea A. & Stan O. The ancient legendary island of PEUCE - myth or reality? Journal of Arechaeological Science, vol. 53, pp 521-535, 2015.

[26] Romanescu G. & Stoleriu C. Exceptional floods in the Prut basin, Romania, in the context of heavy rains in the summer of 2010, Natural Hazards and Earth System Sciences, vol. 17, pp 381-396, 2017.

[27] Romanescu G., Cimpianu C.I., Mihu-Pintilie A. & Stoleriu C.C. Historic flood events in NE Romania (post-1990), Journal of Maps, vol. 13(2), pp 787-798, 2017.

[28] Romanescu G., Mihu-Pintilie A., Stoleriu C.C., Carboni D., Paveluc L.E. & Cimpianu C.I. A Comparative Analysis of Exceptional Flood Events in the Context of Heavy Rains in the Summer of 2010: Siret Basin (NE Romania) Case Study, Water, vol. 10(2), 216, pp 1-17, 2018.

[29] Romanescu G., Chalov S., Stoleriu C.C., Mihu-Pintilie A., Angileri S.E., Kuznetsova Y., Cama M. & Maerker M. Geomorphologic map of the 1st Mutnaya River, Southeastern Kamchatka, Russia, Journal of Mountain Science, vol. 14(2), pp 2373-2390, 2017.

[30] Romanescu G., The tourist potential of coasts and deltas. A look at the romanian coastal areas, Parthenon Verlag, Geist & Wissenschaft, Kaiserslautern und Mehlingen, 2012.

ACTA GEOBALCANICA
5-2, 2019, pp. 103-110

# DETECTION OF THE MULTI-TEMPORAL DYNAMICS OF THE VEGETATION COVERS IN THE ALGERIAN STEPPE BY REMOTE SENSING CASE OF THE KESDIRE ZONE (NAAMA WILAYA)

DOI: *https://doi.org/10.18509/AGB.2019.12*
UDC: *551.585.55:528.931.021(65)*

**Nadjla Bentekhici, Ahmed Zegrar, Sid-Ahmed Bellal**

*University of Oran2, Faculty of Earth and Universe Sciences,*
*Department of Geography, Centre of Spaces Techniques, Algeria,*

corresponding author: bentekhicinani@gmail.com

submitted: *28.04.2018*
accepted: *26.08.2018*
published: *184.01.2019*

**Abstract**

The Algerian steppe is very affected by the ecological and climatic imbalance; the degradation of the natural environment is currently a serious problem following silting, wind erosion, overgrazing and clearing.

The extent of degradation in the semi-arid zone (commune of Kesdire in Naama wilaya) has led to a significant regression of the vegetation cover, requires a better understanding in order to see how to fight against this plague and propose adequate facilities.

Through this work, we have tried to show, on the one hand, the potential of using remote sensing for the detection of the dynamics of the steppe cover and its spatiotemporal evolution from the treatments carried out on Landsat 5 satellite images and 8 (March 1987 and March 2015). On the other hand, to provide decision-makers with information on the state of the vegetation cover in this area.

The method used is based on the interpretation of the treatments (calculations of MSAVI vegetation indices and soil brightness IB) on Landsat satellite images, these digital treatments made it possible to analyze the multi-temporal dynamics of the vegetation cover and identifying areas of degradation within 28 years.

The results of our study show that the state of the vegetation cover and its evolution seem alarming, our study area lost 22.22 % of its natural vegetation during the last quarter of the century. This change informs about the different changes that the municipality of Kesdire has experienced.

Key words: Remote sensing, dynamic vegetation cover, MSAVI, soil gloss index, change maps.

## INTRODUCTION

The degradation of semi-arid ecosystems in Algeria has become a palpable fact that hinders progress and rural development. In these exceptionally fragile environments, the decline in vegetation is an alarming progression. The ecosystem is subject to a long, hot, dry season and low average annual rainfall. The combination of climatic and edaphic conditions makes the steppe a fragile environment exposed to a regression of natural vegetation. We are witnessing a profound change in the steppe ecosystem where the wind equipment (sand) replaces the steppe vegetation (alfa).

In front of this situation, however, it is essential to be able to analyze the vegetation cover in order to identify problem areas (degradation). This analysis involves the manipulation of a considerable amount of information to describe the vegetation of the steppe zone of Kesdire commune. The use of remote sensing is then essential.

Thanks to satellite images, it is possible to map vegetation cover at timescales. For a better understanding of the physical and biological processes that govern the dynamics of plant ecosystems, remote sensing data can also be used to learn about the consequences of possible changes in the distribution of plant cover, so as to establish more sustainable management solutions. For this purpose, a diachronic study of the images acquired in March 1987 (Landsat 5) was carried out in March 2015 (Landsat 8).

## STUDY ZONE

The area concerned by this study is the southwestern part of the high plains of Oran. It is administratively attached to the wilaya of Naâma, it is the commune of Kesdire. It is located about 150 km north-west of the city of Naâma, it occupies an area of 6,378 $km^2$, it is characterized by a population density is 1.2 inhabitant/$km^2$. A commune is victim of its geography and a vast steppe country degraded by intensive and reflective grazing.

The natural vegetation of the study area is characterized by a steppe physiognomy saved in the mountains where the remains of primeval man-made forests of Pinus Halepensis and juniperus phoenicea remain. Apart from these forest species, the aspect of the steppe changes with the rainfall gradient and the nature of the soil. The southern steppe Oran is dominated by the following plant formations:

- Alfa (Stipa tenacissima) steppe ;
- White sagebrush steppe (Artemisia herba Alba);
- Spartan Steppe (Lygeum spartum);
- Halophyte steppe;
- Psamophyte steppe.

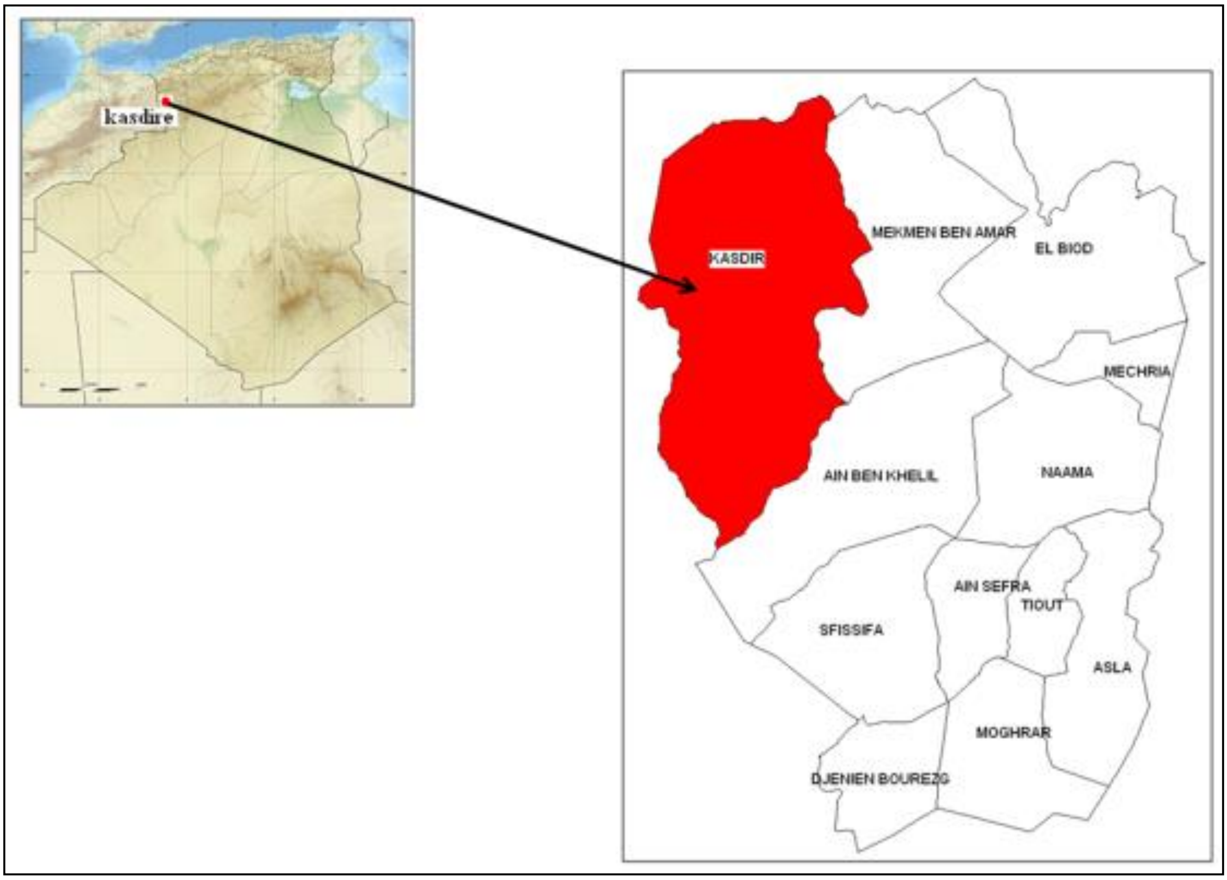



**Figure 1.** Location of the study area

## METHOD OF WORK AND DATA USED

The site chosen for this work is the commune of Kesdire, this zone presents the characteristics of the semi-arid environments subjected to the processes of degradation of the natural environments. To characterize the state of degradation of vegetation cover and soils in this region, we have the following satellite images:

- Image of LANDSAT 5 satellites taken in March 1987 with a resolution of 30m.
- Image of LANDSAT 8 satellites taken in March 2015 with a resolution of 30m.

They were taken during the months of March, the period when seasonal chlorophyll vegetation is present.

We applied the trichromatic three channels (4, 3 and 1) for the Landsat 5 satellite image and (5.4 and 2) for the Landsat satellite image.

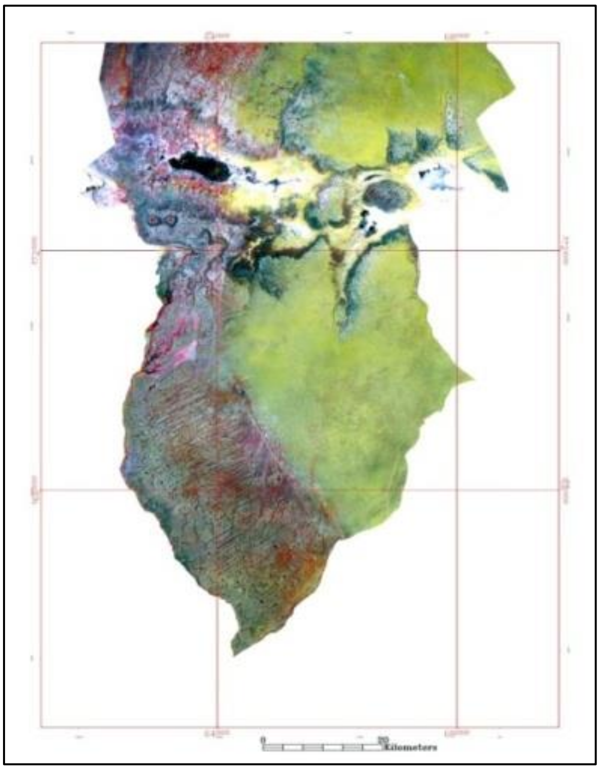


**Figure 2.** Trichromatic (4,3,1) image 1987

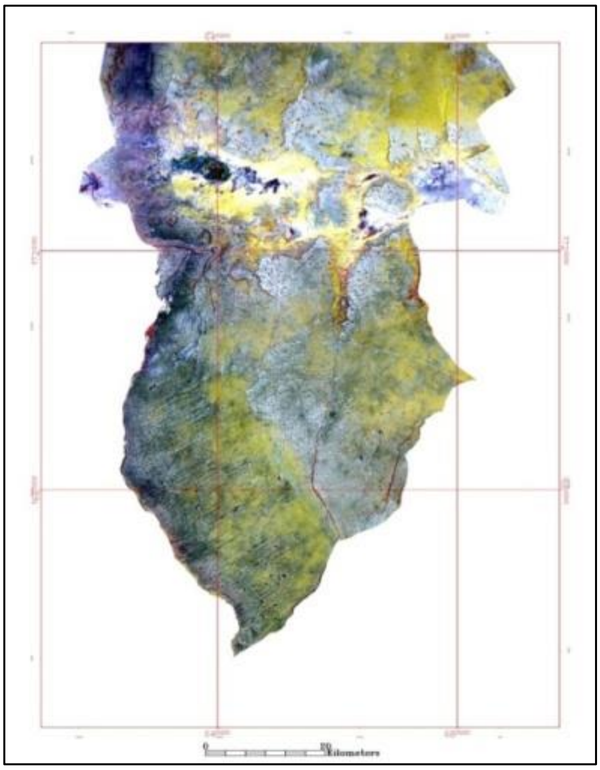


**Figure 3.** Trichromatic (5.4.2) image 2015

Satellite images have been transformed following the conventional image processing chain; namely: the correction of geometric distortions. The correction of the geometric distortions of the image taken in 1987 was made compared to the 2015 image. It is an image-to-image correction using the closest neighbor polynomial approach of degree 1. Then, as shown Figure 4 is a flowchart of a variety of different treatments according to arranged steps.

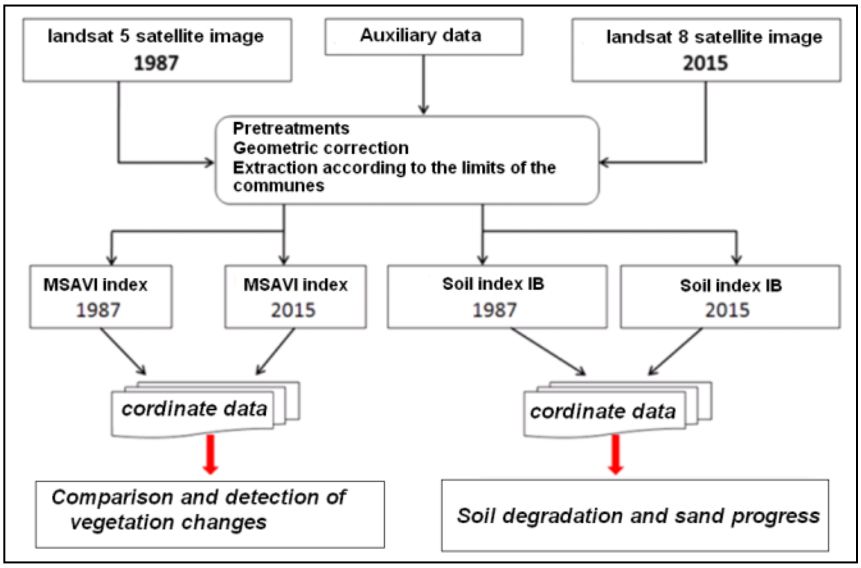



**Figure 4** Flowchart of the method of work.

## WORK RESULTS

Spatio-temporal monitoring of soil cover in semi-arid regions of Algeria such as Kesdire using satellite imagery is of paramount importance for a regional inventory of this vegetation cover, as well as that its spatial variation. The consequences that result from this variation can be irreversible on the state of soil degradation (Defries et al., 2000, Bannari et al., 1995).

We try to use satellite images in order to extract a key parameter in the monitoring and mapping of vegetation cover, we studied statistically over a period of 28 years by applying the index that takes into account soil influence Modified Soil-Adjusted Vegetation Index MSAVI, Qi et al. (1994) propose an improvement in the vegetation index adjusted for SAVI soil. In their MSAVI Modified Soil Vegetation Index, the L-shaped adjustment parameter that characterizes the soil and its rate of vegetation cover, L is no longer a constant, but is automatically adjusted to local conditions. The expression of the MSAVI index is the same as that of the SAVI index. The difference is in the L factor, which depends on the soil right, the NDVI and the weighted difference vegetation index. It was created to minimize the effect of bare floors. The MSAVI index is widely used in the low vegetation zone as the case of the steppe. The MSAVI is calculated by the following formula and by the two channels the red (R) and the near infrared (PIR).

$$\boldsymbol{MSAVI} = \frac{\mathbf{2}\boldsymbol{PIR} + \mathbf{1} - \sqrt{(\mathbf{2}\boldsymbol{PIR} + \mathbf{1})^{\mathbf{2}} - \mathbf{8}(\boldsymbol{PIR} - \boldsymbol{ROUGE})}}{\mathbf{2}}$$

It is therefore through this index that we have chosen to compare the diagnoses relating to the state of vegetation in the Kesdire area. High values of MSAVI represent chlorophyllian activity and low values show bare soils.
The crossing of the image of the 1987 MSAVI index and the 2015 MSAVI index makes it possible to carry out the two-year vegetation cover change chart (Figure 7), the MSAVI 2015 index and coded by the red color, MSAVI 1987 and coded by the yellow color.
The interpretation of the map of the changes makes it possible to detect the regressions in green, the evolution in red and no change in yellow, the western part of the zone has experienced significant degradation and a decline in vegetation.

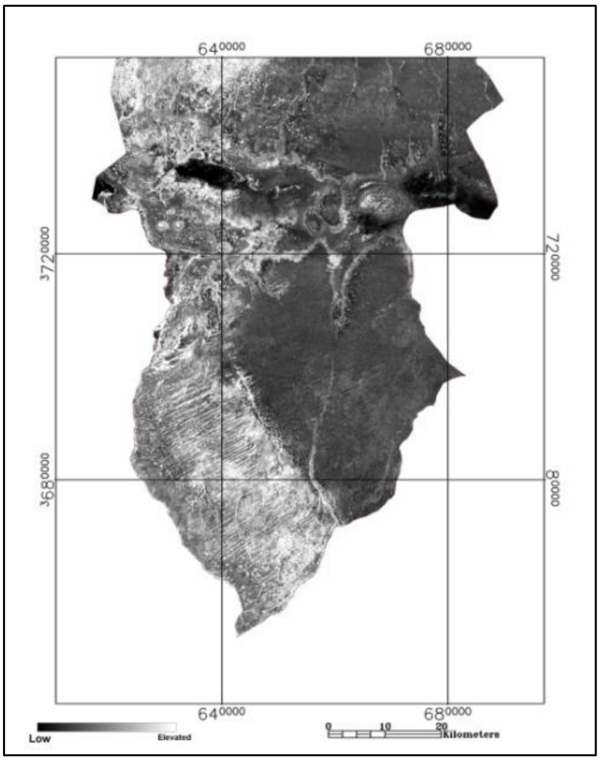



**Figure 5.** Image of the 1987 MSAVI index

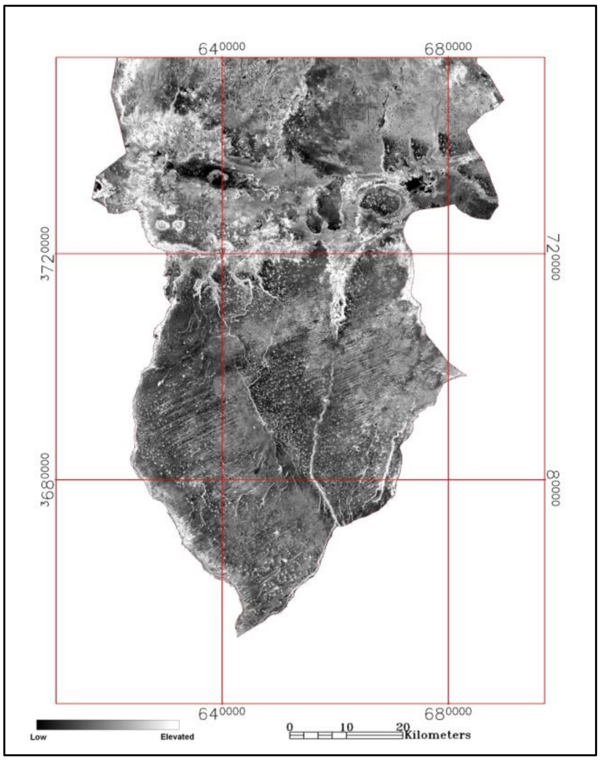



**Figure 6.** Image of the MSAVI 2015 index

The MSAVI indices (Figure 5 & Figure6) by their crossing (Figure7) have clearly shown that there has been a very significant regression during the last 28 years (1987-2015), this is due to the degradation of the vegetation cover caused, in particular, by the problem of overgrazing and excessive exploitation and the problem of drought and the advancement of sand. The green color of the index of change shows the degradation of the steppe vegetation cover.
Thresholding has been applied to the MSAVI of the 2015 image to find the different intervals of the values of this index, respectively corresponding to the two classes selected (Table 1). By a simple application model these same inte rvals were found on the MSAVI of the 1987 image.

**Table 1.** Coverage rate of vegetation cover between 1987 and 2015

| | Year **1987** | | Year **2015** | |
|---|---|---|---|---|
| | Ha | % | Ha | % |
| Absence of chlorophyllous activity (bare soil) MSAVI values: -5 to 0.05 | 353721.24 | 70.37 | 465445.17 | 92.59 |
| Chlorophyllous activity (vegetal cover) MSAVI values: 0.05 to 1 | 148922.64 | 29.62 | 37198.71 | 7.4 |
| Total | 502643.88 | 100 | 502643.88 | 100 |

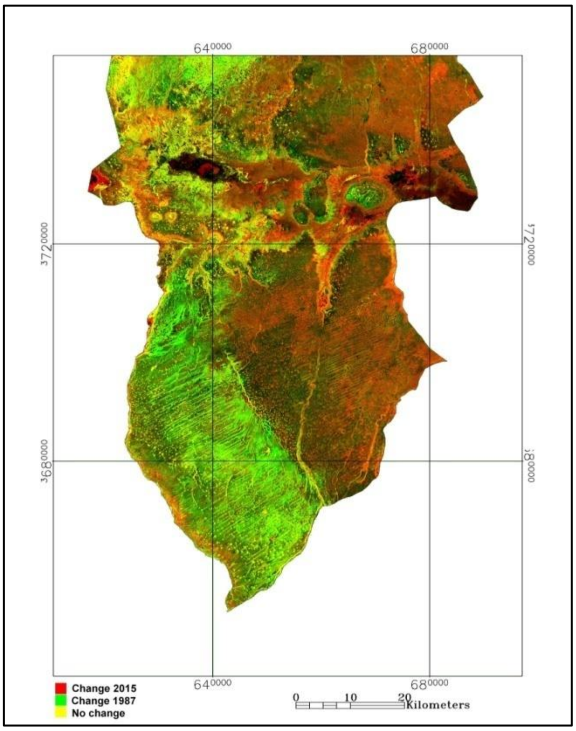



**Figure 7** Map of changes in vegetation cover between 1987 and 2015

The reading of Table 1 and the interpretation of the two MSAVI threshold maps (Figures 8 and 9) clearly show the degradation of the environment. The "bare soil" class increased considerably in 2015 compared with 1987, while the other "vegetative cover" class experienced a reverse scenario to the detriment of the former.

The thresholding of the two MSAVI (1987 image and 2015 image) revealed significant changes in vegetation cover. Formerly with a good recovery rate (map of vegetation cover in 1987), this vegetation has disappeared and given way to the extension of bare soil and sandy accumulations.

The rate of recovery by the steppe vegetation cover has experienced a very strong regression it went from 29.62% to 7.4%, a decline of 111723.93 (22.22% of the vegetation cover) this is the obvious sign of the problem of silting in the region from Kesdire.

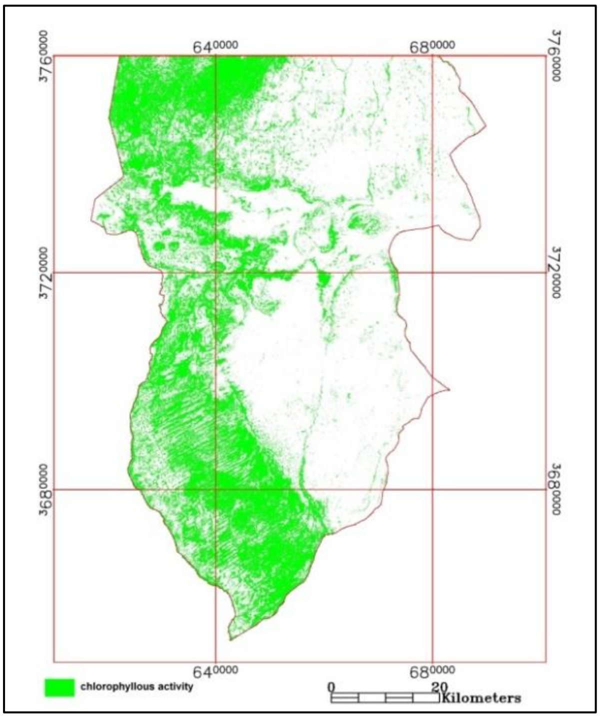



**Figure 8** Map of vegetation cover in 1987

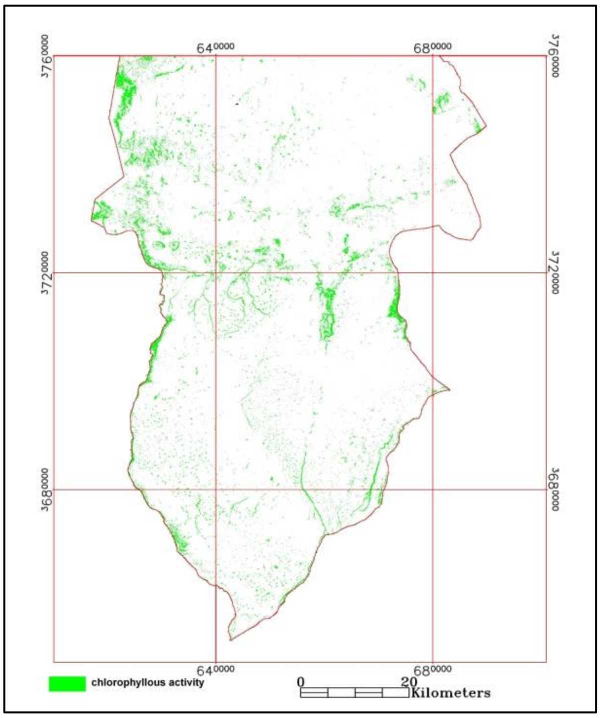



**Figure 9** Map of vegetation cover in 2015

In order to detect the evolution of bare soils and sandy accumulations we applied the index of gloss of the soil on the two images 1987 and 2015. This is calculated from the red and near-infrared bands according to the expression:

$$\boldsymbol{IB = \sqrt{PIR^2 + R^2}}$$

It makes it possible to clearly distinguish between vegetated surfaces and bare floors, The IB highlights:

Dissociates mineral surfaces from vegetable blanket

- Mineral surfaces - strong value, reflective surfaces.
- Vegetation - average value of IB.
- Very wet soil water - low value, absorbent surfaces.

A threshold has been applied to the IB of the 2015 image to find the different intervals of the values of this index, corresponding respectively to the three classes selected (Table 2). By a simple application model these same intervals were found on the IB of the 1987 image, we detected three classes, very wet waters and soils, vegetation cover and mineral surfaces (bare soils and sandy accumulations).

The reading of Table 2 and the interpretation of the two IB thresholding maps (Figs 12 and 13) clearly show the degradation of the environment. The "mineral surfaces" class increased considerably in 2015 compared to 1987, while the other "vegetative cover" class experienced a reverse scenario to the detriment of the former.

The analysis of the two threshold maps makes it possible to describe the following mutations:

- A regression of the vegetation cover by a percentage of 14.55%.
- An evolution of the mineral surfaces by a percentage of 14.79%.

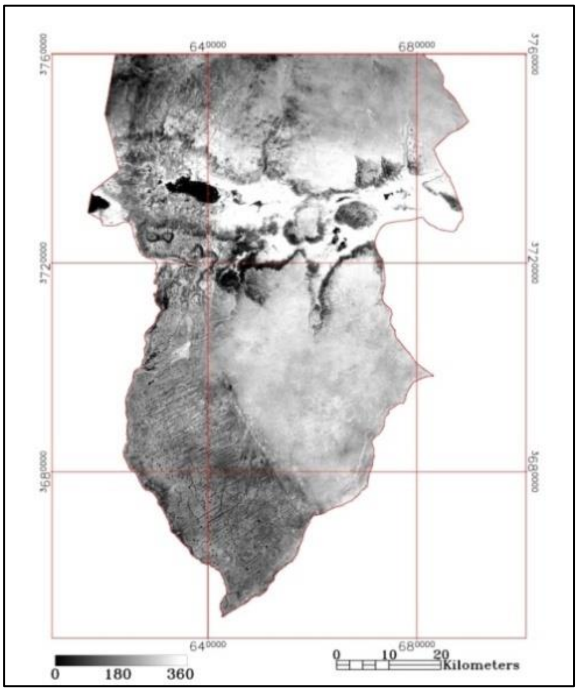



**Figure 10.** Index of brightness of the ground in 1987

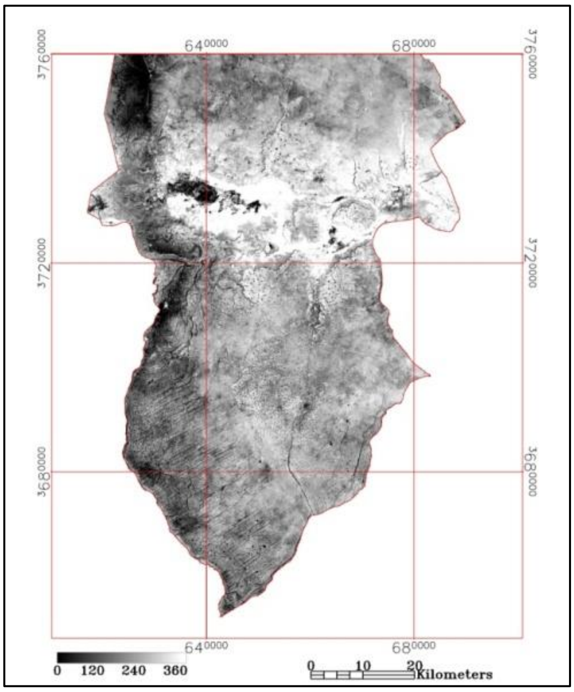



**Figure 11.** Soil gloss index in 2015

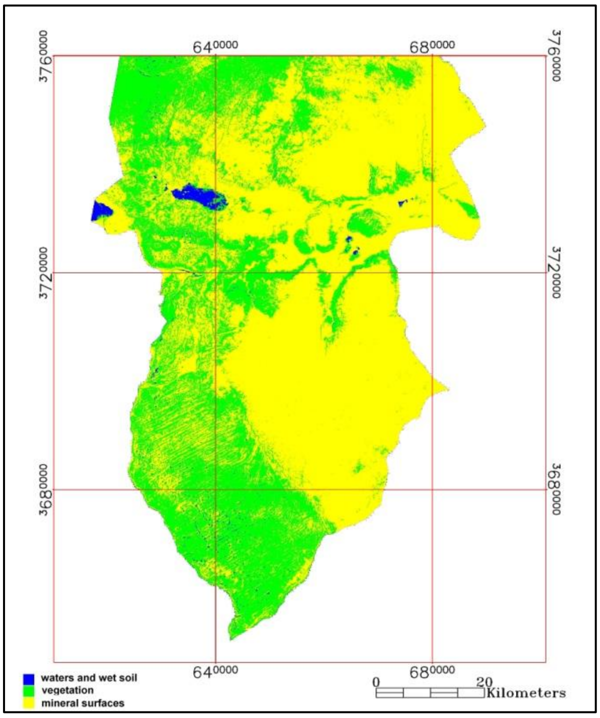



**Figure 12.** Thresholding of the index of gloss of the ground in 1987

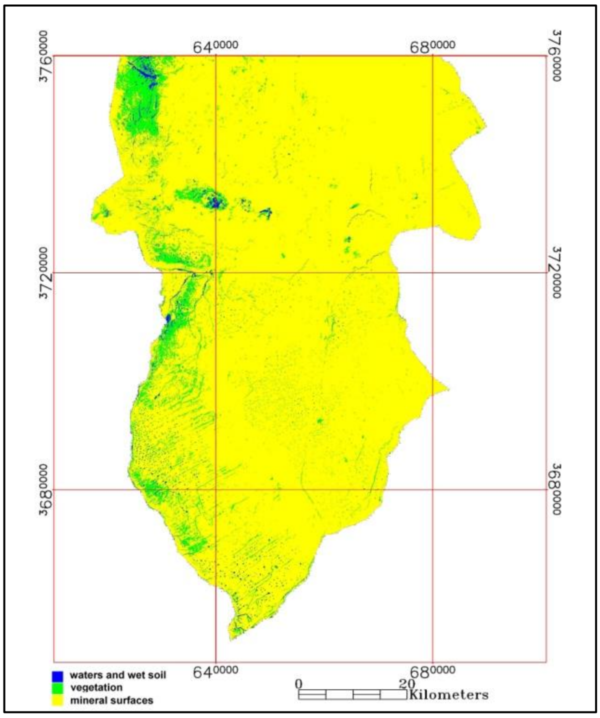



**Figure 13.** Thresholding of the index of gloss of the ground in 2015

**Table 2.** Statistics of the threshold of the index of brightness of soil (IB) of 1987 and 2015

| | Yers 1987 | | Yers 2015 | |
|---|---|---|---|---|
| | Ha | % | Ha | % |
| **Water and very wet soil** | 5665.96 | 0.92 | 3503.88 | 0.69 |
| **Vegetable cutlery** | 104062 | 20.7 | 30910.95 | 6.14 |
| **Mineral surfaces** | 393917 | 78.36 | 468234.48 | 93.15 |

## CONCLUSION

Along this work we have tried, using remote sensing data, to understand the degradation of plant cover and steppe soils in Kesdire commune.

The use of multi-date (1987 & 2015) Landsat 5 and 8 satellite data-based approaches allowed us to obtain a set of interpretative photo maps of MSAVI indices and soil gloss that, in turn, helped us to see the changes in the environment, copiously regressive and progressive.

From these images we were able to establish vegetation cover maps of both dates. These images have been processed and analyzed. We based on the calculation of the indices and the classification of these indices to highlight the characteristics of the soil surface in a semi-arid environment.

The use of remote sensing data allowed us to follow at a regional scale the spatiotemporal evolution of the dynamics of the vegetation cover and the nature of the soil over a period of 28 years. At the end of this study, it appears that LANDSAT's numerical data processing methods provide a very efficient contribution to the mapping of vegetation cover in this area.

According to our estimates using satellite image index calculations, between 1987 and 2015, 22.22% of the canopy area is currently silted. This figure is alarming and shows the extent of the phenomenon in the steppe region of southwestern Algeria.

The maps obtained are cartographic documents intended to enlighten decision-makers and planners on the problems of regression of vegetation. Faced with this document, decision-makers, local elected representatives, developers, pastorals and ecologists can define in the short term priority intervention actions, and in the long term sector-wide planning and management with a view to combating climate change.

## REFERENCES

[1] Haddouche I., Mederbal K., Bouazza M. & Benhanifia K., 2004. Utilisation de la télédétection pour l’étude de la déforestation. Cas de la région de Djelfa. Colloque Méditerranéen sur la Gestion Durable des Espaces Montagnards. Dept. Sc. de la Terre et Agronomie, Univ. Tlemcen, 10-11 Oct.2004. 10 p.

[2] Abdelkrim Bensaid., 2006. SIG et télédétection pour l’étude de l’ensablement dans une zone aride : le cas de la wilaya de Naama (Algérie). Thèse Pour obtenir le grade de Docteur de l’Université Joseph Fourier-Grenoble 1 Discipline : Géographie, 319p.

[3] Smahi Z., 1997. Intégration des données physiques et socio-économiques dans un SIG pour la gestion pastorale dans une zone de la région steppique. Centre National des Techniques Spatiales, Arzew, Algérie, Thèse de magister, 87 p.

[4] Defries R.S., Hansenand J.R.G. 2000. Townshend, Global Continuous Fields of Vegetation Characteristics: A Linear Mixture Model Applied to Multi-Year 8 km AVHRR Data’, International Journal of Remote Sensing, Vol. 21, N°6-7, pp. 1389-1414.

[5] Julian Barbalata. 1996. Analyse diachronique de la dynamique des milieux naturels par télédétection satellitaire. International archives of photogrammetry and remote sensing. Vol. XXXI, part B7. Vienna pp. 53–58.

[6] Tarik B. Bouchetata Et Arslan A. Bouchetata. 2005. Dégradation des écosystèmes steppiques et stratégie de développement durable. Mise au point méthodologique appliquée à la Wilaya de Nâama (Algérie). *Développement durable et territoires* [En ligne], Varia, 2005.

[7] Abdelaziz Boudjadja. 2011. La région steppique d’Ain Ben Khellil et sa zone humide Oglat Ed Daïra (Naâma, Algérie) Plaidoyer pour une gestion et un aménagement durables. Courrier de l’environnement de l’INRA n° 61, décembre 2011 pp. 105-119.

[8] Plan de gestion du site de oglet ed daira wilaya de naama projet dgf/gef/pnud-alg/g35/2005 « conservation de la biodiversité et gestion durable des ressources naturelles des sites de mergueb (M’sila), Oglet Ed Daira (Naama ) et Taghit (Bechar). Décembre 2005.

[9] Haddouche I, 2009, la télédétection et la dynamique des paysages en milieu semi-aride en Algérie : cas de la région de Naama. Thèse pour l’obtention de grade de Docteur en biologie option écologie végétale. Université Abou Bakr Belgaid Tlemcen, Algérie 259p.