

# CALCULATION OF THE NATIONAL AREA OF THE REPUBLIC OF KOSOVA

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**Key words:** national area, ellipsoid GRS80, map projection, Kosovaref01, Republic of Kosova.

## SUMMARY

The practice in a field of geospatial data in Kosova, calculation of areas makes automatically by using computer software directly in flat surface (map projection). This method is also used in cases of large areas calculations, as the state area, bypassing the distortions came from the process of map projecting. Based on this methodology, the value of the territory of the Republic of Kosova in the state coordinates system Kosovaref01 is 10905km<sup>2</sup>.

The methodology used for calculating in our research, estimates based on the reference ellipsoid GRS80. The calculation is performed by applying three methods, the first of which is characterized as the most accurate, while the others were used as control methods for comparing with the first one.

Calculations were performed based on the Kosova border line, produced by the Kosova Cadastral Agency as National Mapping Organization of Kosova, and published under the Global Map ([www.iscgm.org](http://www.iscgm.org)).

In the beginning of research, some analyzes were performed on the test and calculation model to be used in our research. Analysis to determine the model test was carried out by creating three trapezoid networks, from which the trapezoid network with ribs  $\Delta\phi=2'30''$  and  $\Delta\lambda=3'30''$  was accepted as a test model for calculating the state area of Kosova.

As the first method of calculating was used the empirical calculating of the area on full ellipsoid trapezoids, while incomplete trapezoid areas along the border were initially estimated in the state coordinate system and then based on the centroids they were reduced to referent ellipsoid. The state area of Kosova calculated with first method was 10907.101996km<sup>2</sup>.

The second method was realized by using of ArcGIS software, where were calculated automatically the area of trapezoids and those along the state border, as well as the coordinates of their centroids. Then with the mathematical formulas, all areas were reduced in ellipsoid GRS80. Under the second method, the value of the state area of Kosova was 10907.077975km<sup>2</sup>.

The third method was carried out as the second one, with the only difference that the division of Kosova's territory was under the interval 1cm/km of isograms. The state area calculated with third method was 10907.088855km<sup>2</sup>.

Based on three applied methods, it can be concluded that the value of area of the territory of the Republic of Kosova in GRS80 ellipsoid is 10907km<sup>2</sup>, i.e. 2km<sup>2</sup> bigger than the area calculated at the flat surface of the state map projection.

# NJEHSIMI I SIPËRFAQES SHTETËRORE TË REPUBLIKËS SË KOSOVËS

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**Fjalët kyçe:** sipërfaqe shtetërore, elipsoidi GRS80, projekcioni hartografik, Kosovaref01, Republika e Kosovës.

## PËRMBLEDHJE

Praktika Kosovare në fushën e të dhënave gjeohapësinore, llogaritjen e sipërfaqeve e bën në mënyrë automatike duke përdorur softuerat kompjuterik, respektivisht duke llogaritur sipërfaqet në rrafshin e projekcionit hartografik. Kjo metodë përdoret edhe në rastet e llogaritjeve të sipërfaqeve të mëdha, si sipërfaqja e tërë shtetit, duke i anashkaluar shformimet të cilat vinë si rezultat i projektimit të sipërfaqes prej elipsoidit në rrafshin e projekcionit hartografik, pikërisht në sistemin e koordinatave shtetërore. Në bazë të kësaj metodologjie, vlera e territorit të Republikës së Kosovës e llogaritur me softuerat kompjuterik në sistemin e koordinatave shtetërore Kosovaref01 është  $10905\text{km}^2$ .

Metodologjia e përdorur në hulumtimin tonë bazohet në llogaritjen e sipërfaqes shtetërore në elipsoidin referent shtetëror, respektivisht në elipsoidin GRS80. Llogaritja është realizuar duke aplikuar tre metoda, prej të cilave e para karakterizohet si më e sakta, ndërsa dy të tjerat shërbejnë për kontrollin e llogaritjes së metodës së parë.

Llogaritjet u realizuan mbi kufirin e Kosovës të publikuar në kuadër të HGB-së, e punuar nga Agjencia Kadastrale e Kosovës si institucion shtetëror hartografik i Kosovës dhe publikuar në ueb faqen [www.iscgm.org](http://www.iscgm.org).

Në fillim, u realizuan disa analiza mbi përcaktimin e test modelit që do të përdorej për llogaritjet e sipërfaqes. Analiza për përcaktimin e test modelit u realizua duke krijuar tre rrjete trapezash, prej të cilëve rrjeti i trapezave me brinjë  $\Delta\phi=2'30''$  dhe  $\Delta\lambda=3'30''$  u pranua si test model mbi të cilin do të bëhet llogaritja e sipërfaqes së Kosovës.

Metoda e parë nënkuptonte llogaritjen empirike të drejtpërdrejtë të sipërfaqes me ndihmën e formulave për llogaritjen e sipërfaqes së trapezit në elipsoid, ndërsa sipërfaqet e paplota përgjatë kufirit shtetëror fillimisht u llogaritën në rrafsh dhe pastaj në bazë të pikës qendrore të sipërfaqes ata u reduktuan prej rrafshit të projekcionit në sipërfaqen e elipsoidit. Shuma e të gjitha sipërfaqeve të llogaritura dha vlerën përfundimtare të sipërfaqes së Kosovës prej  $10907.101996\text{km}^2$ .

Metoda e dytë u realizua me ndihmën e softuerit ArcGIS, në të cilin u llogaritën automatikisht sipërfaqet e trapezave dhe sipërfaqeve përgjatë kufirit në rrafshin e projekcionit hartografik, si dhe koordinatat e pikave qendrore të tyre (centroideve), që pastaj me ndihmën e formulave adekuate të bëhet reduktimi i tyre në elipsoidin referent GRS80. Sipas metodës së dytë, vlera e sipërfaqes ishte po ashtu  $10907.077975\text{km}^2$ .

Metoda e tretë u realizua në mënyrë identike si në metodën e dytë, me të vetmin dallim që ndarja e territorit të Kosovës u bë në bazë të izokoleve me ekuidistancë  $1\text{cm/km}$ . Sipas kësaj metode, vlera e sipërfaqes të Kosovës ishte po ashtu  $10907.088855\text{km}^2$ .

Në bazë të tre metodave të aplikuara, mund të konkludohet se sipërfaqja përfundimtare e territorit të Republikës së Kosovës në elipsoidin GRS80 është  $10907\text{km}^2$ , për  $2\text{km}^2$  më e madhe se ajo në rrafshin e projekcionit hartografik shtetëror.

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## **1. INTRODUCTION**

Calculation of the national area of territory of the Republic of Kosova became as a result of different values for its surface that we encountered in Kosovo literature, and various web site pages. Not recognizing the accounting methodologies of existing values, in our research are not analyzed existing values, but values are quoted and cited their source. Nowadays when we have technology that enables elimination of random errors and errors coming from human factor, is a sin that values with high national interest not to be unique. In the Republic of Kosova, calculation of areas proceeds automatically by using computer software directly in flat surface (map projection). This method is also utilized in cases of large area calculations, as the state area, bypassing the distortions which come from the process of map projecting. Based on this methodology, the value of the territory of the Republic of Kosova in the state coordinates system Kosovaref01 is 10905km<sup>2</sup>. Because the entire territory of Kosovo lies within the area of a secant cylinder, all deformation values throughout Kosovo are with minus values, which means that the Kosovo area decreases during its projecting from ellipsoid in to map projection, which means that real area of Kosovo in referent ellipsoid is greater than calculated area in the flat surface of state map projection. Research for calculation of the national area of the Republic of Kosova has been realized within the diploma thesis of Fisnik Ismaili under leading of prof.dr. Bashkim Idrizi, at the Faculty of Civil Engineering and Architecture of the University of Prishtina. Calculations were performed based on the official Kosovo border, published from the Kosova Cadastral Agency as national mapping agency of Kosova, which is available and free downloadable at the ISCGM's web page [www.iscgm.org](http://www.iscgm.org). The calculation of the national area in referent ellipsoid, i.e. in ellipsoid GRS80, was used as the methodology for calculation of national area. The calculation is performed by three methods, of which the first is characterized as the most accurate, while the other two methods were used as control methods. As the first method of calculating was used the empirical calculating of the area on full ellipsoid trapezoids, while incomplete trapezoid areas along the border were initially estimated in the state coordinate system and then based on the centroids they were reduced to referent ellipsoid. The second method was realized by using of ArcGIS software, where were calculated automatically the area of trapezoids and those along the state border in map projection, and then with the mathematical formulas to be reduced in ellipsoid GRS80. The third method was carried out as the second one, with the only difference that the division of Kosova's territory was under the interval 1cm/km of isograms.

## 2. CALCULATION METHODOLOGY AND TEST MODEL

### 2.1 Mathematical model for calculation of national area

Calculations of national areas have to be done by reducing the flat surface of state map projection in to national reference ellipsoid. Main purpose of this calculation methodology is getting the homogenous values of national areas for all countries entire world. Otherwise, the sum of all countries and regions will not correspond with the total area of reference ellipsoid. Because there is no any mathematical model for direct calculation of all national area in to ellipsoid based on geographical coordinates of border line, calculation has to be combined with two calculation steps. First step is direct calculation of full trapezoid areas in ellipsoid, and the second step contains two sub steps: first calculation of incomplete trapezoids inside the state border line in map projection, and then to reduce them in to reference ellipsoid surface.

Final national area arises as sum of all calculated trapezoids and reduced incomplete trapezoids (figure 1.).

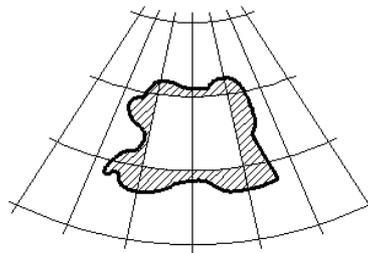


Fig. 1. Scheme of calculation methodology (Idrizi B., 2006)

#### 2.1.1 Calculation of trapezoid areas in reference ellipsoid

The formula for calculation of trapezoid areas created between two meridians and two parallels, bases on the differences between the geographical coordinates (longitude and latitude) between them, and the reference ellipsoid parameters, is (Idrizi B., 2010):

$$\overline{AB} = \overline{CD} = M d\varphi$$

$$\overline{AD} = \overline{BC} = r d\lambda = N \cos \varphi d\lambda$$

$$dS = MN \cos \varphi d\varphi d\lambda = R^2 \cos \varphi d\varphi d\lambda$$

$$S = \iint_{\lambda_2 \varphi_2}^{\lambda_1 \varphi_1} MN \cos \varphi d\varphi d\lambda = \iint_{\lambda_2 \varphi_2}^{\lambda_1 \varphi_1} \frac{b^2 \cos \varphi}{(1 - e^2 \sin^2 \varphi)^2} d\varphi d\lambda$$

$$S = b^2 \frac{(\lambda_2 - \lambda_1)^2}{2\rho^2} \left[ \left( \frac{\sin \varphi_2}{1 - e^2 \sin^2 \varphi_2} + \frac{1}{2e} \ln \frac{1 + e \sin \varphi_2}{1 - e \sin \varphi_2} \right) - \left( \frac{\sin \varphi_1}{1 - e^2 \sin^2 \varphi_1} + \frac{1}{2e} \ln \frac{1 + e \sin \varphi_1}{1 - e \sin \varphi_1} \right) \right]$$

$$S_E = b^2 \frac{(\lambda_2 - \lambda_1)^2}{2\rho^2} \left[ \frac{\sin \varphi}{1 - e^2 \sin^2 \varphi} + \frac{1}{2e} \ln \frac{1 + e \sin \varphi}{1 - e \sin \varphi} \right] \Big|_{\varphi_1}^{\varphi_2} \quad \dots (1)$$

### 2.1.2 Calculation of incomplete trapezoid areas in reference ellipsoid

The methodology for calculation of incomplete trapezoids inside the state border line follows two separate sub-steps: first calculation of areas in the flat surface of map projection, and then reducing of calculated areas from map projection in to reference ellipsoid.

First sub-step, calculation of areas for incomplete trapezoids inside the state border line, performs by using bellow formula (Idrizi B., 2006):

$$S = \frac{1}{2} \sum_{i=1}^n x_i * (y_{i+1} + y_{i-1}) \quad \dots (2)$$

The following second sub-step is reduction of calculated areas from flat surface of map projection in the reference ellipsoid surface by using next formulas (Idrizi B., 2010):

$$p = m_0^2 \left( 1 + \frac{\overline{Y}^2}{2R^2} + \frac{\overline{Y}^4}{24R^4} \right)^2 \quad \dots (3)$$

$$d_p = p - 1 \quad \dots (4)$$

$$S_E = S - S \cdot d_p \quad \dots (5)$$

## 2.2 Source data

Because the type of our research touch directly state area, the state border line as source data has to be obtained from the official national mapping authority. In a case of the Republic of Kosova, the Kosova Cadastral Agency as responsible governmental institution has already published the state border line within the Kosova's Global Map dataset, which is free downloadable from the ISCGM's web page [www.iscgm.org](http://www.iscgm.org) (September, 2011). This border line has been used for performing all calculations within the research.

## 2.3 Creating model for calculation of national area of Kosova

At the beginning, some test models were created as potential models to be used for calculation process. Analyses to determine the final model were realized by creating three trapeze networks which covered whole area of Kosova, with ribs  $\approx 1\text{km}$ ,  $5\text{km}$  and  $10\text{km}$ . For all options, reduction values were calculated, from which as more estimated the trapezoid net with ribs  $\Delta\phi=2'30''$  and  $\Delta\lambda=3'30''$  has been selected as final model for calculation (Ismaili F., 2011). All divided territory in ribs with mentioned dimensions can be seen in next figure 1.

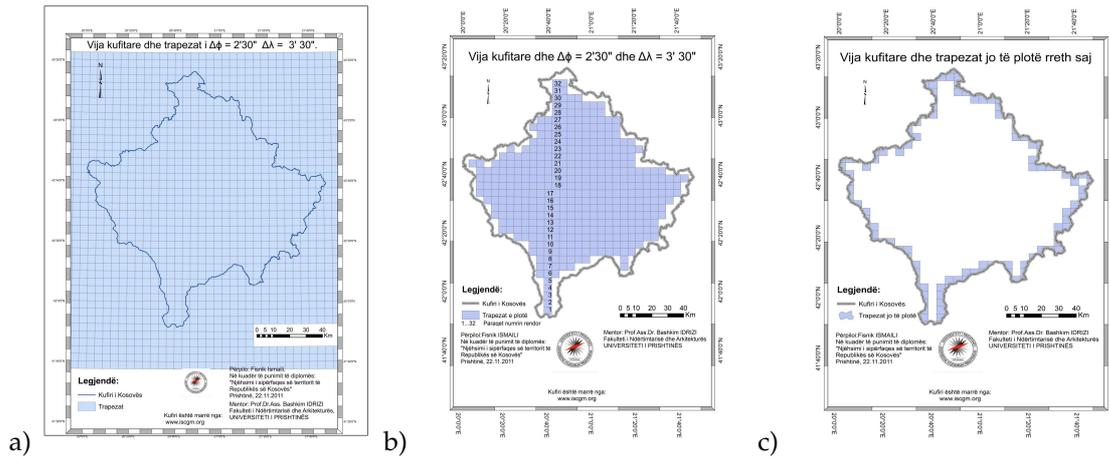


Fig. 1. a) Dividing of territory of Kosova in trapezoids with  $\Delta\phi=2'30''$  and  $\Delta\lambda=3'30''$  (Ismaili F., 2011) b) full trapezoids inside state border; and c) incomplete trapezoids inside the state border line

### 3. CALCULATION OF NATIONAL AREA

Prerequisite for calculation the national area of Kosova is defining the state coordinate system parameters, in which the source data (border line) was developed. The parameters of the state coordinate system of Kosova, known as Kosovaref01 are given in the next table (Idrizi B., et al 2009).

Table 1: Parameters of Kosovaref01

|                          |                         |
|--------------------------|-------------------------|
| <b>Datum</b>             | ETRS89                  |
| <b>Ellipsoid</b>         | GRS80                   |
| <b>Map projection</b>    | Gaus-Kryger             |
| <b>Prime meridian</b>    | Greenwich               |
| <b>Central meridian</b>  | 21°E                    |
| <b>Scale factor</b>      | 0.9999                  |
| <b>False easting</b>     | 7500000m                |
| <b>Prime parallel</b>    | Equator                 |
| <b>False northing</b>    | 0m                      |
| <b>Origin of heights</b> | Trieste – Molo Sartorio |

Based on upper given details of state coordinate system of Kosova, it is so clear that the national area will be calculated in to ellipsoid GRS80 (Moritz H, 1992).

In continuation of this paper, three explained methods in previous chapter will be used for the area of the Republic of Kosova.

### 3.1 Trapezoids and area of incomplete trapezoids inside the state border line

#### 3.1.1 Empirical calculation

Calculation of the area with this method represents the most reliable mathematical model with the higher accuracy in comparing with the others. This method implied direct empirical calculation of area of trapezoids in the surface of ellipsoid, while incomplete trapezoids inside the state border line initially have to be estimated in flat surface of map projection and then to be reduced in to the referent ellipsoid surface. Formulas which should be used within this method were given in point 2.1 second chapter.

Based on established model for calculation in second part of chapter two, for 416 complete trapezoids in 32 separate rows were calculated areas with formula 1. It is important to mention that trapezoids along the same row have same value of areas. Total area of 416 trapezoids is  $9220.057636\text{km}^2$ .

Second set of data, which contains 156 areas of incomplete trapezoids inside the state border line were calculated by combination of software and empirical method by using formulas 3-5. Firstly, by using software, areas of incompleted trapezoids in flat surface of map projection were obtained automatically, as well the coordinates of their centroid points were exported as a list of orthogonal coordinates followed by the value of area. Then, by using formulas 3-5, all 156 areas were reduced from flat area into the surface of ellipsoid GRS80. Total value of all reduced 156 areas in ellipsoid is  $1687.044360\text{km}^2$ .

Final national area of Kosova based on first method is (Ismaili F., 2011):

$$S_E = S_{tr} + S_{in, tr} = 9220.057636 + 1687.044360 = 10\ 907.101996\text{km}^2$$

#### 3.1.2 Semiautomatic calculation by using ArcGIS

The second method was implemented in a similar way as the second step of the first method. With aim to have values for comparing with the results of first method, another random network with trapezoids has been created. Trapeze dimensions were preserved to be identical as those in first method ( $\Delta\phi=2'30''$  and  $\Delta\lambda=3'30''$ ), with the only difference that the origin of the trapeze network was changed. As a result of changing of origin point, in total 574 polygons were created, two more then the number of trapezoids in first method.

In this case, for all 574 polygons, initially the flat areas and orthogonal coordinates of their centroids were obtained from the map projection, automatically by using ArcGIS software.

Then, all polygons areas were reduced by using mathematical model determined in second chapter with formulas 3-5 and exported values from ArcGIS.

Because of combination between the software and empirical calculation methods, the second method was entitled as semiautomatic calculation by using ArcGIS.

Total sum of calculated area for all 574 polygons in reference ellipsoid GRS80 for the national area of Kosova, by using second (semiautomatic) method was  $10907.077975\text{km}^2$  (Ismaili F., 2011).

### 3.2 Dividing national area under interval of 1cm/km of isograms

The third method was used mainly for rough control of both upper calculated values with the previous methods. Calculation methodology was identical as the second one, with the only difference that the division of the territory of Kosova in this case was based on isograms with interval 1cm/km. As a result of division of the territory of Kosova based on isograms, in total 26 polygons were formed, with large differences in their area values, from 0.017km<sup>2</sup> to 3665km<sup>2</sup>. Big differences between the polygon areas directly affect the accuracy of the calculated values.

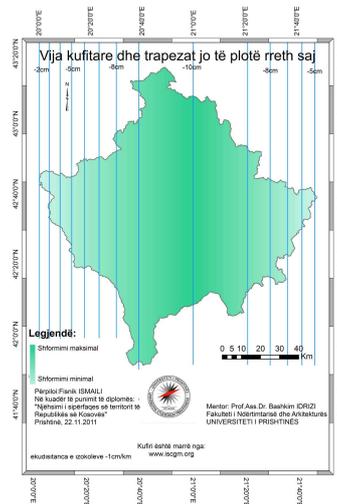


Fig. 2. Dividing of territory of Kosova under interval 1cm/km of isograms (Ismaili F., 2011)

Same as in the second method, for all 26 polygons, initially the flat areas and orthogonal coordinates of their centroids were obtained from the map projection, automatically by using ArcGIS software. Then, all polygons areas were reduced by using mathematical model determined in second chapter with formulas 3-5 and exported values from ArcGIS. As result of this method, which because of inhomogeneous areas treats as a control method, the total sum of calculated area for all 26 polygons in reference ellipsoid GRS80 for the national area of Kosova was 10907.088855km<sup>2</sup> (Ismaili F., 2011).

## 4. CONCLUSIONS

Based on three applied methods, it can be concluded that the value of national area of the territory of the Republic of Kosova in GRS80 ellipsoid is 10907km<sup>2</sup>, for 2km<sup>2</sup> larger than the area calculated at the flat surface of the state map projection (Ismaili F., 2011).

State map projection of Kosovo has non-proportional distribution of distortions across its territory. All distortions have negative prefix, which means that the territory of Kosova reduces its dimensions in all territory during the process of projecting from ellipsoid into flat surface of map projection. This comes as a result of utilization the scale factor (0.9999) which doesn't match the characteristics and dimensions of the Kosova territory.

Because of reduction of the national area of Kosova during the projecting process, its national

area is smaller in surface of map projection compared with the area in referent ellipsoid. In our research, it was recognized that the difference between two areas is  $\approx 2\text{km}^2$ , i.e. 0.18%. Despite the fact that the basis of on which calculations were performed are prepared by the official mapping authority of Kosova, the calculated area  $10907\text{km}^2$  in paper cannot be taken as final for Kosova, because Kosova has not yet begun the process of demarcation of its border with neighboring countries, except Macedonia.

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## BIOGRAPHICAL NOTES



**Bashkim IDRIZI**, was born on 14.07.1974 in Skopje, Macedonia. He graduated in geodesy department of the Polytechnic University of Tirana-Albania in 1999year. In 2004, hot the degree of master of sciences (MSc) in Ss.Cyril and Methodius University-Skopje. In 2005 he had a specialization for Global Mapping in Geographical-Survey Institute (GSI) of Japan in Tsukuba-Japan. On year 2007, he held the degree of Doctor of sciences (PhD) in Geodesy department of Ss.Cyril and Methodius University-Skopje. He worked in State Authority for Geodetic Works from May 1999 until January 2008. During those period, in 2004 he appointed for head of cartography department, i.e. geodetic works. From October 2003 up to January 2008, he worked as a outsourcing lecturer in State University of Tetova. From February 2008, he works as a cartography and GIS Professor at the State University of Tetova-Tetova. He continuo with working as outsourcing lecturer in geodesy department of the University of Prishtina-Kosova. He is the author of three cartography university books, and more than 70 papers published and presented in national and international scientific conferences related to geodesy, cartography, GIS and remote sensing. From March 2010, he is appointed as president of Geo-SEE (South-European Research Association on Geo Sciences). On November 2011, he has been elected as first President of Pan-national Association of Albanian Surveyors.



**Murat Meha** is a University Professor and Deputy Head of the state Border Demarcation Commission. He has been teaching at the University of Prishtina - Kosovo since 1988. He has also taught for ten years at Tetova University (FYR of Macedonia). He worked for five years as Manager of SEO Ferronikeli, for three years as a CEO of Kosova Cadastre Agency, in different funded EAR projects, USAID project, KTA etc. His teaching and research concern survey, cadastre, Land Administration and Land management. and related educational and capacity building activities. He is currently the member of Kosova Surveyor Association. Main publications of Mr Meha are on survey, cadastre, Land Administration and Land management. He published two University books, two books for Kosovo Cadastre Agency, one book translated, and several school geographic atlases and maps. More than 80 professional and science papers in different professional magazines, symposiums, conferences etc. Most of those articles are available on Internet at: FIG, ICC, Euro Geographic, WPLA, CELKCenter, FAO GIM International etc.



**Pal NIKOLLI.** Graduated at the Geodesy branch of Engineering Faculty, Tirana University. In 1987 has been nominated lecturer in the Geodesy Department of Tirana University. In 1994 has been graduated Doctor of Sciences in cartography field. During this period, have taught the following subjects: “Cartography” (for Geodesy and Geography students) and “Geodesy” (for Civil engineering & Geology students). Actually he is lecturer and tutor of the following subjects: “Elements of Cartography” (for Geography students), GIS (for Geography students, diploma of first and second degree) “Interpretation of Aerial Photographs” (for Geography students, diploma of first degree), “Satellite Images” (for geography students, diploma of second degree) “Thematic Cartography” (for Geography students, diploma of second degree) and “Topography-GIS (for the Geophysics students, diploma of second degree). Mr. Nikolli is the author and co-author 8 textbooks (Elements of Cartography and Topography, Elements of Cartography, Geographic Information Systems, Processing of satellite images, Cartography, etc), 3 monographs (History of Albanian Cartography, Mirdita on Geo-Cartographic view, etc), more than 40 scientific papers inside and outside of the country, more 40 scientific & popular papers, etc. Has participated in several post graduation courses of cartography and GIS outside of the country (1994, 2000 - Italy), etc.



Mr. **Fisnik ISMAILI**, was born on 13.10.1988 in Lipjan-Kosova. He graduated in geodesy department of the University of Prishtina – Faculty for Civil engineering and Architecture-Prishtina, on October 2011. His diploma thesis was “*Njehsimi i sipërfaqes së territorit të Republikës së Kosovës*”.

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