



**BULGARIAN ACADEMY OF SCIENCES
INSTITUTE OF INFORMATION AND COMMUNICATION
TECHNOLOGIES**



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**INNOVATIVE METHODS TO SUPPORT DECISION-MAKING IN
WILDLAND FIRES OR FLOODS**

ABSTRACT OF PhD THESIS

Supervisor:

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Sofia, 2021

The PhD thesis was discussed and allowed to be defended during an extended session of the Department of „Record №10“ at IICT-BAS, which had been held on 30.10.2020.

The full volume of the dissertation is 122 pages. It consists of an introduction and four chapters. The list of references contains 107 items. The work includes 6 Appendices. The text of the dissertation includes 5 tables and 57 figures.

The defense of the PhD thesis had been held on at in Room, Block, IICT-BAS.

Approved by Supervising Committee:

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Title: **INOVATIVE METHODS TO SUPPORT DECISION-MAKING IN WILDLAND FIRES OR FLOODS**

I. GENERAL CHARACTERISTICS OF THE PhD THESIS

Topicality of the problem

Climate-related events such as floods, storms, heat waves, snowfall and droughts account for nearly ninety percent of all major disasters in the last two decades. Bulgaria is exposed to a number of natural threats such as floods, landslides, earthquakes, forest fires, droughts, strong winds, heavy snowfall, extreme temperatures and hail. The disasters caused by these phenomena have adverse economic effects on the country. According to Bulgaria's National Statistical Institute (NSI), natural disasters and fires have caused nearly 1 billion US dollars in damage. from 2010 to 2019. Over 600 million US dollars was spent during this period for recovery, and others over 100 million US dollars are invested in rescue and emergency activities. The risks of disasters facing the country are expected to increase in view of growing urbanization and industrial development and climate change. For this reason, the development of innovative methods to support decision-making in natural disasters plays an important role in the sustainable development of the country.

According to the report of the European Commission (EC) in 2018, forest fires have affected more countries than ever before. These fires also have a significant impact on the ecological balance of the planet. The data show that with regard to some of the indicators for the occurrence of forest fires in Bulgaria, the average values typical for the Mediterranean region have been reached and even exceeded many times [1].

According to the international disaster database "EM-DAT", since 1977 45 major disasters have been registered in Bulgaria, and more than 85 percent of them are related to meteorological phenomena. These disasters cause direct damage of more than 1.4 billion US dollars. Floods and extreme temperatures are the most common, with floods being responsible for most of the direct damage and population affected. Floods cause enormous damage to public and private buildings and cultural heritage sites, destroy or damage bridges, dikes and dams, disrupt drinking water supply systems, trigger landslides and flood agricultural land.

Geographic Information Systems (GIS) are modern, multifunctional, computer-based technologies that not only visualize objects in geographical space through digital mapping, but also allow the integration and analysis of interdisciplinary attribute data in a geographical context. Thus, they become a powerful tool for planning, designing and making management decisions in all public spheres and businesses of different nature and scale. One of the applications of GIS technologies is mapping and cartographing and making specialized maps of areas at risk of floods and maps of the threat of floods, fires and more natural disasters [2].

The relevance of the topic is determined on the one hand by the presented data on the huge

damage caused by wildland fires and floods to economies, flora, fauna and human health worldwide and on the other hand by the ability of GIS to create applications to support of solutions in cases of wildland fires and floods.

Object and subject of the research

The object of research are innovative methods for creating Web GIS applications for wildland fires and floods.

The subject of research is open source software and software tools for the development of information system IS supporting decision making in case of wildland fires or floods.

Goals and tasks

The goal of the PhD thesis is:

- at the theoretical level - to study methods for developing web GIS applications and to present a methodology for developing IS, supporting decision-making in cases of wildland fires or floods.
- at the empirical level - to develop and test IP to support decision-making in cases of wildland fires or floods.

The following scientific tasks can be systematized:

1. Theoretical analysis of basic concepts related to the development of IS, supporting decision-making in wildland fires or floods - wildland fires, floods and Geographic Information Systems (GIS).
2. Presentation of a methodology for creating IS supporting decision-making in wildland fires or floods;
3. Development of IS to support decision-making in wildland fires or floods.
4. Collection, analysis, evaluation and processing of available geospatial data for wildland fires and floods;
5. Selection of appropriate software solutions for the development of web GIS applications, in connection with the available open source web GIS software products, in terms of cross-platform integration with stable interoperability of geospatial data;

6. Approbation of the developed IS, supporting decision-making in wildland fires that have occurred in the area of State forestry "Zlatograd".
7. Approbation of the developed IS, supporting decision-making for flood risk in Syunik region, Kapan city in Armenia.

Methods

As the topic of the PhD thesis requires the application of an interdisciplinary approach in conducting research, the following methods were used to perform the research tasks:

1) on a theoretical level:

- bibliographic;
- comparative;
- descriptive;
- mathematical methods.

2) at the empirical level:

- quantitative;
- analysis, synthesis, generalization;
- modeling.

II. VOLUME AND STRUCTURE

The full volume of the dissertation is 122 pages. It consists of an introduction and four chapters. The list of references contains 107 items. The work includes 6 Appendices. The text of the dissertation includes 5 tables and 57 figures.

III. CONTENT

The introduction clarifies the relevance of the problem and presents the methodological parameters of the dissertation, structure, object, subject, goals and objectives.

CHAPTER 1. General information on fires and floods, statistics and similar applications

The first chapter provides a theoretical analysis of the concepts included in the dissertation research: wildland fires, floods, Geographic Information System, European Forest Fire Information System (EFFIS), Advanced Fire Information System (AFIS) and European Flood Information System (EFAS). Official statistics on fires in the period from 2009 to 2018 and floods in the period from 2010 to 2019 in Bulgaria are presented.

Main conclusions to Chapter 1:

- 1) Based on the review of forest fires and floods in Bulgaria from the report provided to the JRC on fires and the NSI on floods, it can be concluded that it is necessary to use GIS for mapping, modeling and visualization of these natural disasters.
- 2) With the development of GIS technologies, opportunities are provided for analysis and visualization of geospatial data in the event of natural disasters, in particular in the case of floods and forest fires.
- 3) From the considered systems (EFFIS, AFIS, EFAS), [3,4,5] for monitoring forest fires and floods based on satellite images, we can conclude that it is necessary to build similar systems at the local level to visualize geospatial data.

CHAPTER 2. Methodology for developing an information system to support decision-making in cases of wildland fires or floods

The second chapter presents a methodology for developing IS to support decision-making in forest fires or floods. Two models that are basic for the development of the Web GIS application are considered: "Model simulating the development of forest fires", "Empirical model with the construction of a digital terrain elevation model for the surrounding geometry of the area." An

"open source architecture for developing a web GIS application" is proposed (Figure 1).

The following components are required to develop a web GIS application (Figure 1):

- Spatial Databases that can provide random access to a huge set of data, processing queries related to spatial relationships. Software that can provide editing and visualization of data from the database, as well as management, quality control of data.
- Cartographic software that reads spatial data from the database, applying rules for formatting and displaying images.
- Server providing a software framework for customizing applications. The map server stores pre-created image tiles and maintains them quickly to make the map refresh faster.
- A web component that can provide visualization of maps in a web browser and create requests to the server.

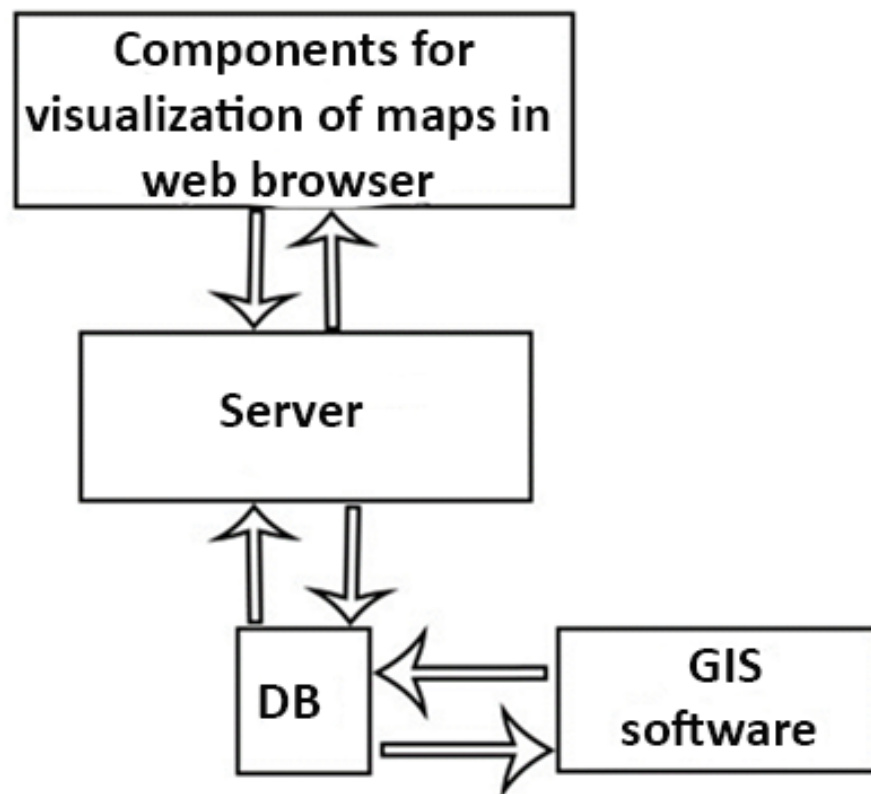


Figure 1. Open source architecture for developing a web GIS application

"Conceptual model of decision support IS in wildland fires or floods" is presented in (Figure 2).

This model is developed on the proposed open source architecture for developing Web GIS applications. It includes the following modules:

- web GIS application;
- OpenWeatherMaps connection with meteorological data;
- EFFIS / EFAS link to satellite data;
- interactive learning module.

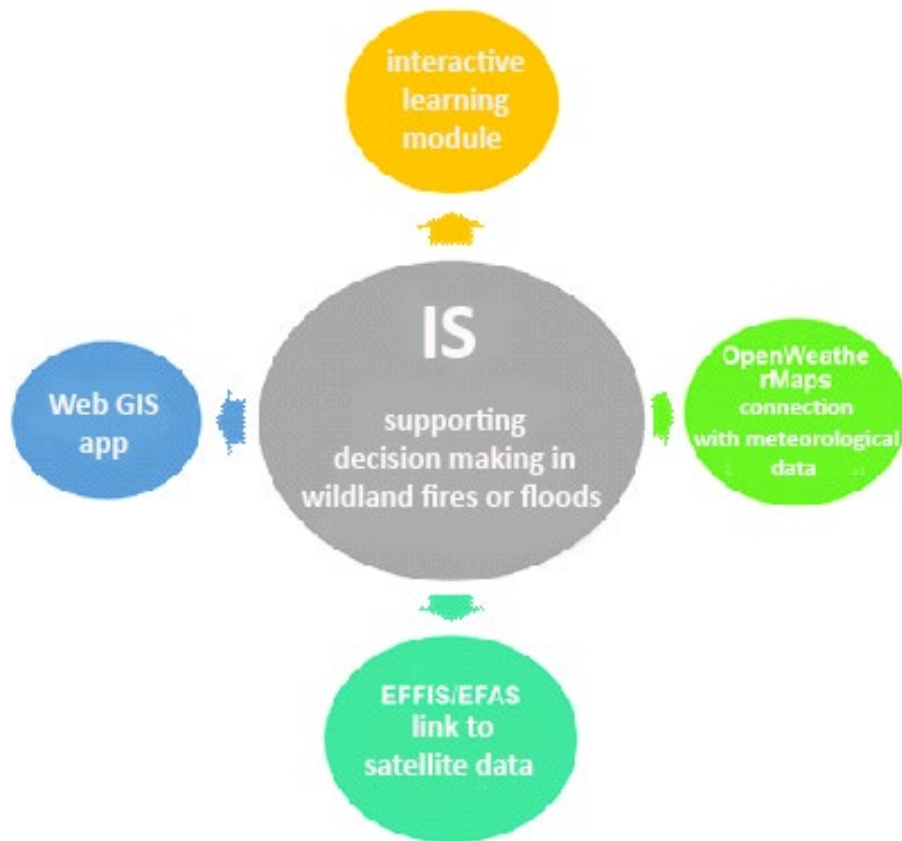


Figure 2. Conceptual model of IS supporting decision making in wildland fires or floods.

Main conclusions to Chapter 2:

- 1) Based on the presented models, the methodology for building IS has been developed, supporting decision-making in the operating room or in the field in case of wildland fires or floods.
- 2) The methodology includes: creation of geospatial data, open source architecture for web GIS application development and conceptual model of IS supporting decision making in the operating room in case of wildland fires and floods.

- 3) The Rothermel model has been chosen as the theoretical basis for the wildland fire simulations, which will be presented in the next chapter.
- 4) The theoretical substantiation of the information system supporting decision-making in case of flood risk uses an empirical model with construction of a digital model of the terrain for the riverbed and surrounding geometry of the zone.

CHAPTER 3. Web GIS application architecture

The third chapter presents the architecture and software implementation of a Web GIS application, which is part of the IS supporting decision-making in wildland fires or floods.

The web GIS application is presented in Figure 3, which is part of an information system to support decision making in cases of wildland fires or floods. The application consists of six layers:

- The first layer is GIS software, which processes the data obtained after simulations by the method of Rothermel fires and floods on an empirical model with the construction of a Digital Terrain Model for the riverbed and the surrounding geometry of the area.
- The second layer is a database for storing geospatial data. The geographical database differs essentially from other databases only in that it has a spatial distinction and in this sense refers to a specific territory. The objects in it have a specific location and have spatial relationships.
- The third layer is a plugin that allows you to convert data to a GeoJson file format.
- The fourth layer is the Web GIS application development environment.
- The fifth layer is the server environment.
- Visualization in a browser is done through a library for visualization of geospatial data on the Web, which builds the sixth layer.

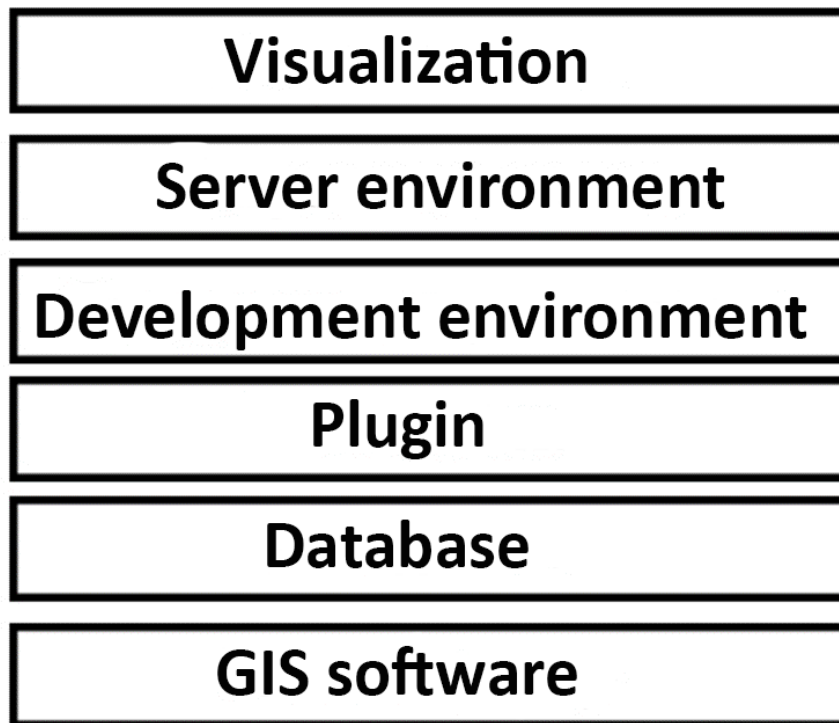


Figure 3. Web application architecture

Software implementation of the web GIS application

To implement the proposed architecture for the development of a web GIS application, which is part of the IS supporting the decision-making in the operating room in case of wildland fires and floods, the following software solutions were used (Figure 4):

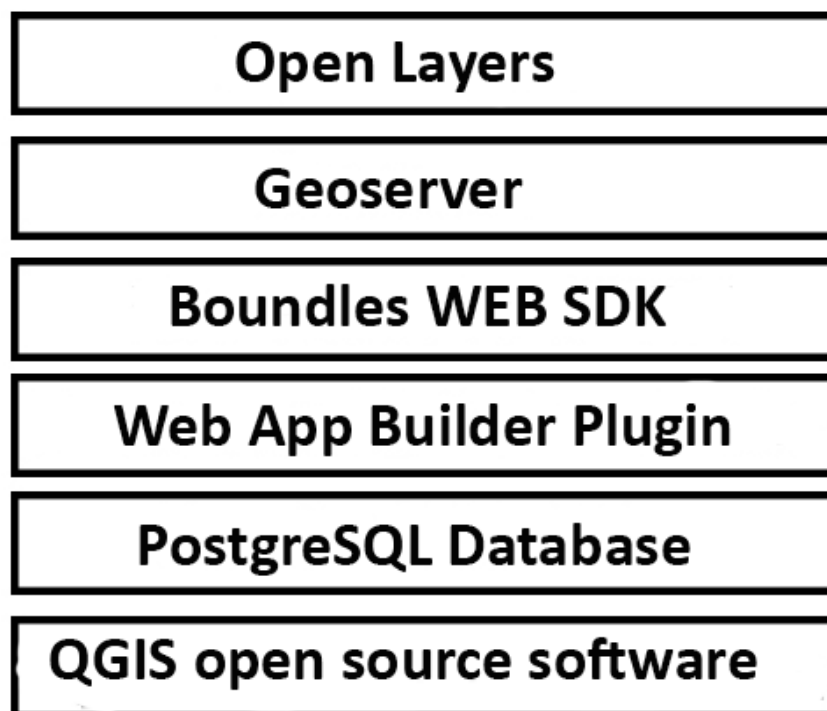


Figure 4. Software implementation of the Web GIS application

- 1) QGIS software

QGIS is open source GIS software that visualizes, manages, edits, analyzes data [6].

QGIS includes:

- analytical functionality through integration with GRASS (Geographic Resources Support System for Analysis),
- SAGA (Automated Geoscientific Analysis System),
- Orfeo Toolbox, GDAL/ OGR (Abstraction Geospatial Data Library) and many other algorithm providers.

QGIS runs on Linux, Unix, Mac OSX and Windows and supports many vector, raster and database formats and functionalities.

2) Database – PostgreSQL

PostgreSQL is a powerful, object-oriented relational open source database system that uses and extends the SQL language, combined with many features that safely store and scale the most complex data loads and can store geospatial data [7]. PostgreSQL has the ability to:

- Geospatial definition of diverse types of geographical objects with different dimensions - point, line and polygon.
- Multidimensional indexing of various geo-objects for speed of access.
- Application of geospatial functions on some of the objects, in relation to inquiries about geospatial characteristics and relationships.

3) QGIS plugin WebAppBuilder

The Qgis WebAppBuilder plugin provides the ability to convert raster and vector layers into a geoJson file, which is convenient and easy to use [8].

4) IS development environment to support decision-making in the operating room in case of wildland fires and floods.

The IS development environment is Boundless WEBSDK, which provides tools and libraries for building JavaScript-based applications. Boundless WEBSDK uses the JavaScript React framework (a library of JavaScript to build user interfaces) to provide modular components that can be used to develop web-based applications [9].

Main conclusions to Chapter 3:

- 1) The architecture of the Web GIS application is described, which is part of the IS, supporting decision-making in the operating room or in the field in case of wildland fires or floods.
- 2) A software implementation of the web GIS application in question is presented
- 3) A methodology for developing a web GIS application is presented, which includes conversion of geospatial data into geoJSON file format, programming with JavaScript, HTML and CSS programming languages, which provide the full functionality of IS and visualization of data on wildland fires or floods.

CHAPTER 4. Application in practice

In the fourth chapter are presented and tested IS for decision support in forest fires in the area of State forestry "Zlatograd" (Figure 5) and in case of flood risk in the area of Syunik, Armenia (Figure 8).

Web application to support decision making in cases of forest fires

General information about the test zone State forestry "Zlatograd" and implementation of the application for wildland fires.

The application of IS, decision support in the operating room in case of wildland fires is focused on specific test areas. These areas cover Natura 2000 sites [10] located in the municipalities of Zlatograd [11], Madan [12] and Nedelino [13]. The information system was developed within the Cross-border project under INTERREG VA "Greece-Bulgaria 2014-2020", called: "Protection of biological diversity in NATURA 2000 sites and other protected areas from natural hazards through a certified framework for cross-border education, training and support of civil protection volunteers based on innovation and new technologies "with the abbreviation: eOUTLAND, (MIS CODE 5011437 and Reg. No. 1672), [14].

Description and implementation

When starting the Web application from index.html, the initial screen of the IS opens (Figure 5), which is developed with program code presented in Appendix 2 and Appendix 3.

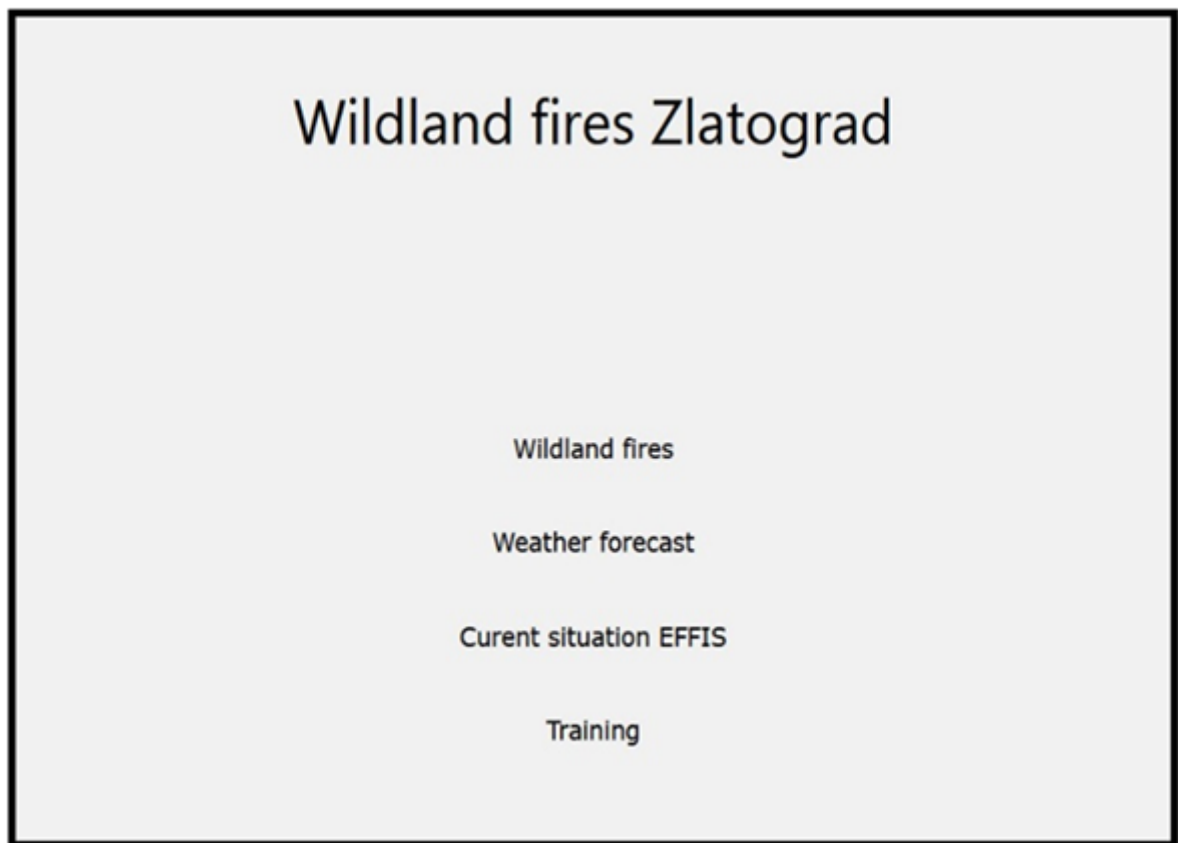


Figure 5. Main menu of the Web application

The following buttons can be selected from the main menu:

- Wildland fires;
- Weather forecast;
- Current situation EFFIS;
- Training.

The Wildland fires button launches the decision support web application in the operating room in case of forest fires (Figure 6).

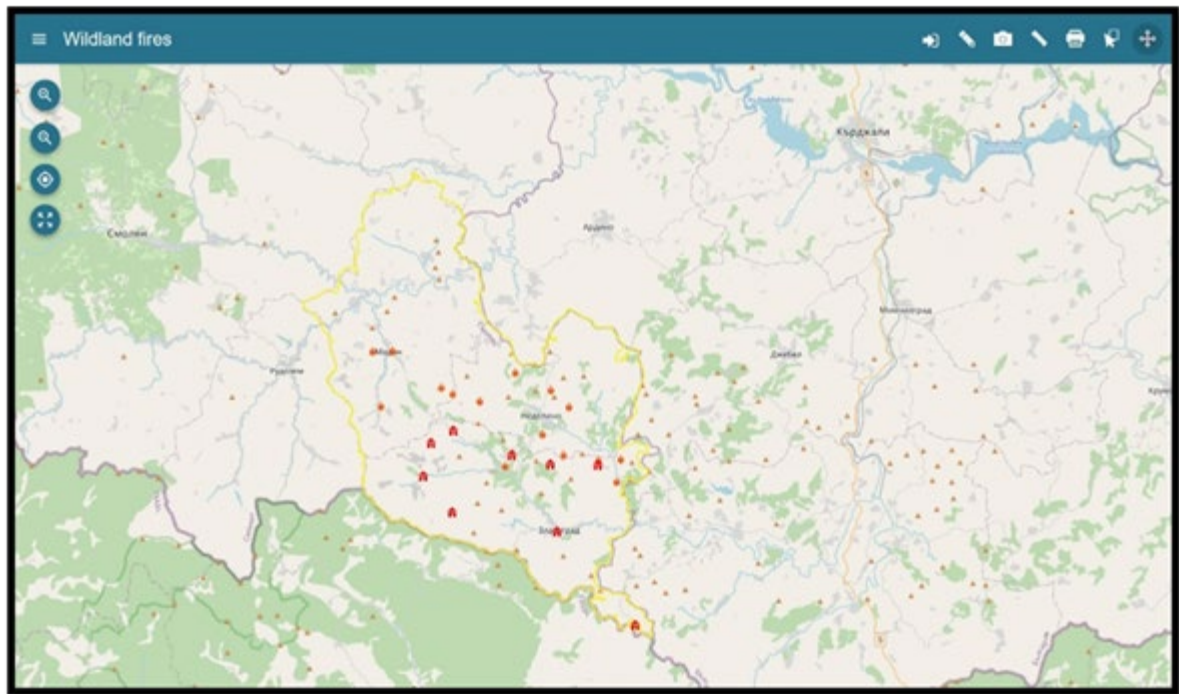


Figure 6. Wildland fires application main screen

Main functionalities of the Web application for wildland fires:

- **Main menu** - the various predefined layers are displayed, which are displayed in the application. They can be turned on, off, their transparency can be changed, the location of the selected layer can be approached, their order can be changed and a new user-defined layer can be displayed by dragging and dropping. The application has a function for searching objects, places, settlements, etc. The application has built-in Base layers that are open source, such as OpenStreet maps, satellite maps, etc., and can be switched according to user requirements.
- **Zoom in function** - with the help of the button the user has the opportunity to zoom in on the object of his interest.
- **Zoom out function** - with the help of the button the user has the opportunity to move away from the object of his interest.
- **Geolocation function** - based on the location of the network, this function visualizes the location of the device that uses the application.
- **Scaling** - this feature allows the user to return to the original scale set in the application.
- **Login function** - allows the user to log in and upload new files containing GIS layers.

- **Drawing function** - allows the user to quickly add a new point (fire) object or polygon (fire zone) to an existing layer to be displayed in real time.
- **Function for exporting a map in .png format**
- **Measurement function** - allows the user to measure the distance between two or more points as well as to calculate the size of the selected study area.
- **Print function** - allows you to quickly print a map on paper.
- **Selection function** - allows the user to choose from the various functions of the layers as well as to remove the selection.
- **Navigation feature** - This feature makes it easier to zoom in, out, and move maps on mobile devices.

Working with layers involves selecting a substrate / base layer / as the base layers can be selected by the user.

The web application has a set of predefined layers that provide different types of data that can help users get information about previous fires in the area as well as fire zones.

In addition, the web application provides information on storage facilities for fire-fighting materials, as well as what tools are included in them to fight fires.

The order of the layers can be changed in real time by dragging.

Predefined layers can be turned off or on according to different user needs. Their transparency can also be changed.

Working with layers includes:

- 1) **Zoom** - the button allows the user to navigate to the selected layer, and when pressed the screen is as close as possible to the selected layer;
- 2) **On/Off** - this button allows the user to turn on or off a layer depending on the needs;
- 3) **Additional menu** - the button opens additional functionalities when working with layers, opening a menu consisting of:
 - **Transparency** - the button allows the user to specify the transparency of the layers;
 - **Download** - the button allows the user to download the selected layer, using the

drawing function to register a new fire on his device;

- **Filter** - the button allows the user to choose exactly what data he wants to visualize from the given layer.

The Web application has a Pop up function (Figure 7) and when marking an object (storage of fire-fighting materials and tools) the necessary data of the groups of firefighters or volunteers operating in the field or in the operating room are visualized from the map.

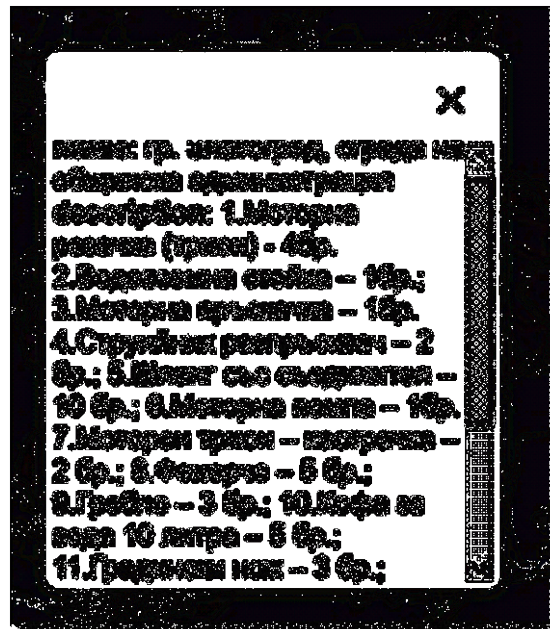


Figure 7. Storage for materials and tools

These data provide more detailed information on the location, type of materials and tools and their availability, so that teams of volunteers and firefighters working in the field can see the nearest storage to the site of the fire.

Figure 7 visualizes information about the location, materials and tools for wildland fire fighting, which are stored in the selected repository.

Working with IS to support decision-making in the operating room and in the field in case of forest fires allows firefighters or volunteer teams in the event of a wildland fire to obtain information about the location of storage facilities with available firefighting materials. The IS allows the registration of a fire through a drawing function and for greater accuracy the GPS coordinates of the device they use are used.

The Web GIS application part of IS for decision support in the operating room in case of floods is focused on specific test areas. They cover the Gegi Dam and the Geganush tailings pond in Armenia. It was developed within the framework of DG ECHO project: “Alliance for disaster Risk

Reduction in Armenia” with acronym: ALTER and Grand Number: 783214 [15].

The data for the development of decision support IS in the case of floods in the Syunik region of Armenia were provided by the American University of Armenia and the Institute of Geological Sciences (Armenia), and are also available in their databases.

When starting the IS from index.html, the initial screen of the IS opens (Figure 8).

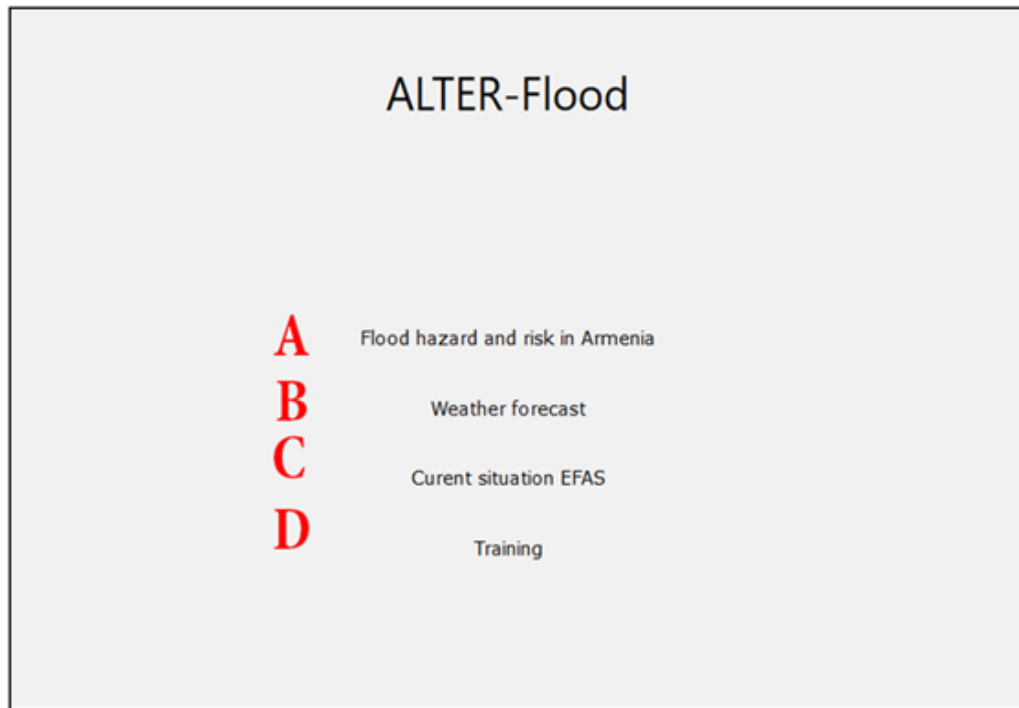


Figure 8. Home screen of the Flood Web Application

The following buttons can be selected from the main menu:

- Flood hazard and risk in Armenia;
- Weather forecast;
- Current situation EFAS;
- Training.

The "Flood hazard and risk in Armenia" button launches the decision support application in the operating room in case of flooding.

The flood app aims to visualize how the tidal wave will propagate in the event of a flood. It shows the most vulnerable buildings such as schools, kindergartens, etc. The application provides information about the nearest and endangered buildings. It thus provides the necessary data and

information to on-site groups that will be useful in responding to and deciding in the event of a flood.

The main features of the flood application are shown in Figure 9.



Figure 9. Main window of the flood application

1. **Zoom in function** - with the help of the button the user has the opportunity to zoom in on the object of his interest.
2. **Zoom out function** - with the help of the button the user has the opportunity to zoom out from the object of his interest.
3. **Geolocation function** - based on the location of the network, this function visualizes the location of the device that uses the application.
4. **Scaling** - this feature allows the user to return to the original scale set in the application.
5. **Main menu** - here are the various predefined layers that are displayed in the application. They can be turned on, off, their transparency can be changed, the location of the selected layer can be approached, their order can be changed, and a new user-defined layer can be displayed by dragging and dropping. The application has a function for searching objects, places, settlements, etc.
6. **Drawing function** - allows the user to quickly add a new object (flood area) to an existing layer to be displayed in real time or to be saved for later analysis.

7. **Photo function** - allows you to export a map in photo format.
8. **Measurement function** - allows the user to measure the distance between two or more points, as well as to calculate the size of the selected study area.
9. **Selection function** - allows the user to choose from the various functions of the layers and also to deselect.
10. **Easy navigation feature** - this feature allows you to easily zoom in, out and move maps on mobile devices

The base layers can be changed according to the user's requirements. Predefined layers: they can be turned off or on according to different user needs. Their transparency can be changed. The application has a rich set of predefined layers that provide different types of data that can help users to analyze the current situation or review different scenarios for the development of the tidal wave in case of a dam failure. The order of the layers can be changed in real time by dragging.

Working with layers (Figure 10):

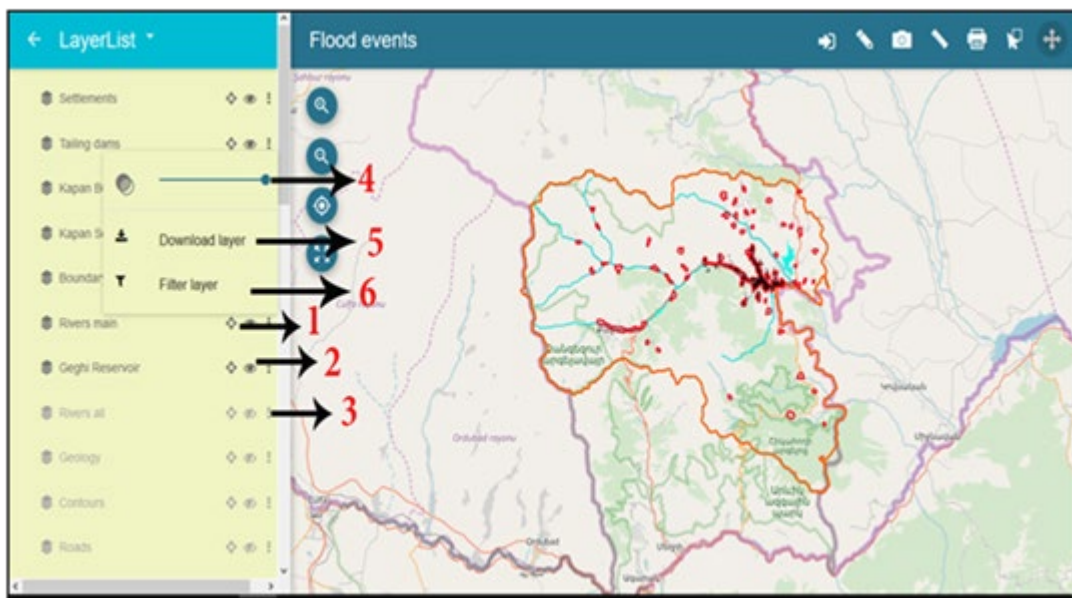


Figure 10. Working with layers

- 4) **Zoom** - the button allows the user to navigate to the selected layer, and when pressed the screen is as close as possible to the selected layer;
- 5) **On/Off** - this button allows the user to turn on or off a layer depending on the needs;
- 6) **Additional menu** - the button opens additional functionalities when working with

layers, opening a menu consisting of:

- **Transparency** - the button allows the user to specify the transparency of the layers;
- **Download** - the button allows the user to download the selected layer, using the drawing function to register a new fire on his device;
- **Filter** - the button allows the user to choose exactly what data he wants to visualize from the given layer.

IS, decision support in the operating room in case of floods has a function to pop up an information window when marking an object on the map as the most vulnerable buildings in case of floods such as schools, kindergartens and others.

The information window displays detailed information about the location and type of the building so that the field teams can assess which is the closest vulnerable point in case of flooding.

Main conclusions to Chapter 4:

- 1) The information systems supporting decision-making in cases of wildland fires - State forestry "Zlatograd" and in case of flood risk in the "Syunik" region of Armenia have been tested.
- 2) The functionalities and capabilities of the IS supporting decision-making in cases of forest fires or floods are presented.

IV. Main deductions and conclusions

Scientific and scientific-applied contributions

Main scientific contributions in the PhD thesis:

- 1) *An analysis* of existing GIS was made, as well as a comparative analysis of open source software - QGIS and commercial software - Esri ArcGIS;
- 2) *An algorithm* for development of Information systems supporting decision making in wildland fires or floods with open source is presented;

Main scientific-applied contributions in the PhD thesis:

- 1) *A methodology* for working with real data has been proposed to visualize parameters for relief, meteorology, plant species and water resources;
- 2) *The architecture* of a web GIS application is applied, which is realized with open source software products and tools.
- 3) *Information Systems (IS)* have been developed and tested to support decision-making in wildland fires and floods.

Guidelines for future research

The results achieved in the PhD thesis outline the following guidelines for future research:

- 1) *Study of* the opportunities provided by the European program Copernicus for satellite monitoring in its part for Emergency Management Services.
- 2) *Complementing* open source software applications with risk assessment algorithms for: critical infrastructure and points of interest (Points of Interest) for different hazard criteria (vulnerability index assessment).
- 3) *Development of a GIS application* for visualization of meteorological data generated by the system for overlay and correction of forecast data via GRIB, WRF, ECMF, EURO4 for forecasts and measurement of microclimatic features applied in the operational mode of MOS schemes and NOWCASTING in forecast data.

V. APPROBAL OF RESULTS AND PUBLICATIONS

The main results obtained in the development of the dissertation are reported in four publications at specialized international conferences:

докладвани в четири публикации на специализирани международни конференции:

1. Dobrinkova N., Stefanov S. Open source GIS for civil protection response in cases of wildland fires or flood events. The 12th International Conference on Large-Scale Scientific Computations LSSC'19, (June 10 - 14, 2019, Sozopol, Bulgaria), Institute of Information and Communication Technologies Bulgarian Academy of Sciences, Large-Scale Scientific Computing. LSSC, 2019. Lecture Notes in Computer Science Springer, 11958, Springer, 2020, ISBN:978-3-030-41032-2, ISSN:1611-3349, DOI:https://doi.org/10.1007/978-3-030-41032-2_35, 309-314, **SJR: 0.427**;
2. Dobrinkova N., Stefanov S. Desktop application developed by open source tools for optimizations in cases of natural hazards and field response. *Studies in Computational Intelligence*, 838, Springer, Cham, 2020, ISBN:978-3-030-22722-7, ISSN:1860-949X, DOI:<https://doi.org/10.1007/978-3-030-22723-4>, 17-30, **SJR: 0.215**;
3. Dobrinkova N., Stefanov S., Hadjitodorov S., Arakelyan A., Amirkhanian A., Barseghyan A., Mnatsakanian S., Drakatos G., Evangelidis Ch., Katsaros V., Boustras G.. Emergency planning and optimizations based on dam break flood risk maps visualized with open source web-GIS tool. 14th FEDERATED CONFERENCE ON COMPUTER SCIENCE AND INFORMATION SYSTEMS FedCSIS 2019, (1-4 September, 2019, Leipzig, Germany), Leipzig University, Polish Information Processing Society, 2019, ISBN:978-83-955416-1-2, ISSN: 2300-5963, DOI: <http://dx.doi.org/10.15439/978-83-955416-1-2>, 309-314.
4. Stefanov S. Open source data for developing desktop application as part of eOUTLAND project. Proceedings of International Conference on Big Data, Knowledge and Control Systems Engineering BdKCSE'2018, (21-22 November 2018), John Atanasoff Society of Automatics and Informatics, 2018, ISSN:2367-6450, p.71-p.79.

The research in the dissertation is part of the results of two international research projects:

1. The Project is co-funded by the European Regional Development Fund (ERDF) and by national funds of the countries participating in the Interreg V-A “Greece-Bulgaria 2014-2020” Cooperation Programme: „Protecting biodiversity at NATURA 2000 sites and other protected areas from natural hazards through a certified framework for cross-border education, training and support of civil protection volunteers based on innovation and new technologies” with acronym: eOUTLAND, (MIS CODE 5011437

and reg. number 1672;

2. DG ECHO project: “Alliance for disaster Risk Reduction in Armenia” with acronym: ALTER and Grand Number: 783214.

VI. ACKNOWLEDGMENTS

I express my sincere gratitude and appreciation to my supervisor Assoc. Prof. Dr. Nina Dobrinkova for valuable guidance, professional competence and assistance in the preparation of the dissertation. Thank you also for your invaluable moral support and patience.

VII. REFERENCES

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[3] Европейската информационна система за горските пожари (EFFIS) - <https://effis.jrc.ec.europa.eu/>.

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[5] Европейска информационна система за наводненията – (EFAS) - <https://www.efas.eu/>.

[6] Qgis - <https://www.qgis.org/en/site/>

[7] Postgresql - <https://www.postgresql.org/>

[8] Webappbuilder - <https://github.com/planetfederal/qgis-webappbuilder-plugin>

[9] WEBSDK - <https://github.com/planetfederal/sdk>

[10] Natura 2000 - <http://natura2000.moew.government.bg/>

[11] Община Златоград - <https://www.zlatograd.bg/>

[12] Община Мадан - <https://www.madan.bg/>


[13] Община Неделино - www.nedelino.bg

[14] eOUTLAND - <https://eoutland.eu/>

[15] ALTER - <http://alter-project.eu/>

VIII. DECLARATION OF ORIGINALITY

Hereby, I declare that I have composed the presented thesis independently on my own and without any other resources than the ones indicated. All thoughts taken directly or indirectly from external sources are properly denoted as such. This work has neither been previously submitted to another authority nor has it been published yet.

Signature: 

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