

## AERIAL FIREFIGHTING OF FOREST FIRES - SPATIAL DATA SUPPORT

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### ABSTRACT:

The main aim of the article is to show the usage of spatial data for support of aerial firefighting of forest fires. First, the support of strategic level decision is shown, and after that, the support of the tactical and operational level is demonstrated. The strategic level decisions are supported with various cartographical outputs showing the distribution and trends of the forest fires in the area of the Czech Republic. These maps are based on the data concerning the emergencies collected on the operational centers of the Fire and Rescue Service of the Czech Republic. The created maps serve as a support for the decisions concerning the strengthening of the assets for aerial firefighting of the forest fires. In this way, the spatial data concerning the emergencies, are used to support the strategic decisions. The outcome of these decisions is the public procurement focused on the selection of the aircraft of the private owners, which will bolster the current state assets for wildfires suppression. The operational and tactical level of aerial firefighting of forest fires is supported with the published layer, which contains the selected places for water supply to the aircraft during the forest fire suppression operation. The places were selected on the regional offices of Fire and Rescue Service of the Czech Republic. The data was sent in the form of Office Open XML Workbook (xlsx) (Microsoft Excel table) to the General Directorate. There the data was collected and processed by the Java program into the form of ArcGIS Server feature layer. This process makes the data available through the whole Fire and Rescue Service of the Czech Republic in a standardized manner.

## 1. INTRODUCTION

### 1.1 Geography and emergencies

Emergencies, which endangers humankind and environment, take place on the earth surface, influence it, and are influenced by it. Because of that fact, the earth sciences play a vital role in the management of all phases of an emergency. From a practical point of view, the geographical information system provides tools for applying the findings of the earth sciences in the daily praxis of protection against the emergencies. This article tries to contribute in a humble manner to this effort on the area of forest fires and wildfires.

### 1.2 Aerial Firefighting Service

The main document, which concerns in the Czech Republic, the aerial firefighting of the forest fires, is the “Guidelines for aerial firefighting of the forest fires” (Směrnice, 2019). It is an agreement between the Ministry of the Interior - General Directorate of Fire and Rescue Service of the Czech Republic and the Ministry of Agriculture. This document defines the System of Aerial firefighting service.

In a framework of this System, the aircrafts of the private owners, aircrafts of the Police of the Czech Republic Air Service, and the voluntary and professional fire units ensure the flights for suppression of the forest fires. The System focuses mainly on the forests under the authority of the Ministry of Agriculture and has regard to the occurrence of the forest ecosystems with the different threat of the forest fires.

This System also covers other forests (forests under the authority of Ministry of Defence in the proving grounds, forest under Ministry of Environment in the national parks), but under different administrative procedures. The System can also be used for the other types of the wildfires than forest fires (grass fires, vegetation fires, or field fires) and also on the other type of fires.

### 1.3 Stations of the Aerial Firefighting Service

The Stations of the Aerial Firefighting Service are all buildings, structures with its technical equipment, and lands (runways, manipulation ways, and safety areas) necessary for carrying out the duties of Station and aircrafts. The Station can be owned by the private operator or Police of the Czech Republic Air Service.

The Stations, owned by the private owner, are selected in the area, where the Stations, owned by the Police of the Czech Republic Air Service, cannot provide sufficient coverage by its assets for the aerial extinguishing of the forest fires.

The area, where the coverage is not sufficient, is determined according to the analysis also based on the cartographical outputs showing the distribution of the forest fires in the area of the Czech Republic and range of flight of the Police of the Czech Republic Air Service.

Each station must have one aircraft for suppression of the forest fires. The preparation of the flight in the case of the emergency must be started in 5 minutes after the request and take-off of the aircraft must take place in 15 minutes.

Each station must also have the reserve of biologically degradable detergent which will be sufficient for minimally 50 filings of the aircraft.

#### 1.4 Selected Places for Water Supply

Selected Places for Water Supply is a place chosen for filing of the aircraft with extinguishing medium. The medium can be a water or water with the small addition of detergent, which enables better contact of the water with burning material.

Regional Fire and Rescue Services choose the Places for water supply in the cooperation with the person responsible for the place and crate for given year the list of the Places. It also sends the list to the General Directorate of Fire and Rescue Service of the Czech Republic, which summarize and actualize the main list of the Places for the whole Czech Republic.

The flights for the aerial extinguishing of the forest fires can be done from all civil airfields, selected places for water supply, or other suitable places chosen by the pilot of the aircraft. The military airport can be used in compliance with its regulations.

## 2. FOREST FIRES IN THE CZECH REPUBLIC

### 2.1 Current situation

In recent years the precipitations (Territorial, 2019) on the territory of the Czech Republic decreases, and forest fires increases (figure 1). There is also an increase of the other types of wildfires which are suitable for deployment of aerial firefighting (Fire, 2019).

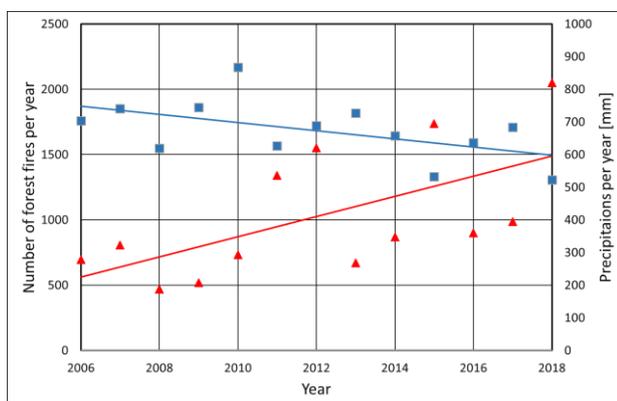


Figure 1. History of the forest fires and precipitation in recent years in the Czech Republic.

These trends signalize that forest fires can be a severe problem in the quite near future.

### 2.2 Trends in regions

The comparison of the number of forest fires occurring in various areas of the Czech Republic is given in the literature (Špulák, 2016). This gives us a static picture of the situation. The more dynamic picture of the situation can be provided by showing the trends in the number of forest fires in various regions (figure 2) and districts (figure 3) of the Czech Republic.

As a source of data for figures mentioned above was used the 13334 records on the emergencies, classified as the forest fires, collected on the operational centers of Fire and Rescue Service of the Czech Republic in the years 2006 - 2018. Small Java program was written to obtain trends in a number of the forest fires in various regions and districts. It goes through the list of forest fire emergencies and classifies and summarise it according to the region, district, and year. When the set of year sums of the forest fires in the given area is obtained, the program uses linear regression (Sedgewick, 2011) in order to determine the trends in amount forest fires in a given area. The tables containing the parameters of the regression, intercept, slope, and coefficient of determination, in a given area are created. Finally, the tables are joined with the appropriate layer of the regions and districts. The join is made according to the standard area codes.

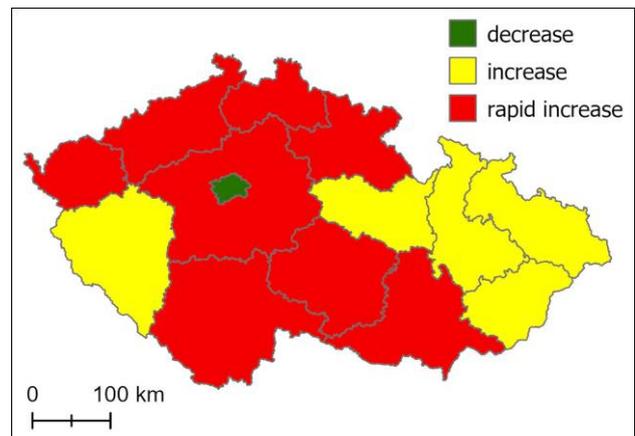


Figure 2. The trends in the number of forest fires in various regions of the Czech Republic.

For visualization of the trends in regions and districts were used the slope obtained through abovementioned linear regression. The slopes were classified into three categories. The first green category signalizes that the slope is less than 0, so the amount of forest fires in a given region decreases with time. In the second, yellow, category the slope is between 0 and the average slope and signalize increase of forest fire over time. In the last, red, category, the slope is above the average and signalize rapid increase.

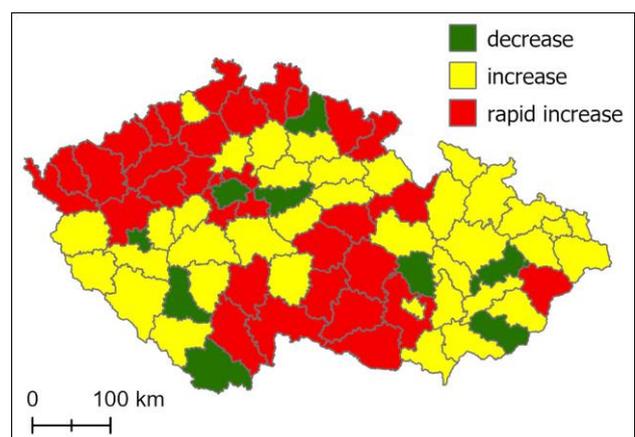


Figure 3. The trends in the number of forest fires in various districts of the Czech Republic.

We can see from figures 2 and 3, that the situation of the forest fires in the Czech Republic is from year to year more and more serious. The areas where the amount of forest fires decreases from year to year is insignificant in comparison with the areas where the amount of forest fires increases from year to year. There is also a substantial quantity of regions where the amount of forest fires increases more rapidly than in the others. In the areas where the amount of forest fires decreases, according to linear regression, the coefficients of determination are low in comparison with other areas.

According to these facts, the forest fires are severe threats to the population, property, and environment and that there is no hope that the situation will substantially improve in the near future.

Because of that fact, great attention must be paid on the means for fighting of large forest fires and wildfires in general. Aerial firefighting of forest fires and wildfires is one of the ways how to realize fighting of such threats. The practical realization of cost demanding aerial firefighting service requires intensive planning. One of the necessary inputs in this planning is the evaluations of the trends in forest fires threat.

### 3. SELECTED PLACES FOR WATER SUPPLY

#### 3.1 The collection of the data

In the case of usage of aircrafts, included into System of Aerial Firefighting Service, during the management of emergencies cannot be excluded the possibility, that the filing the aircraft with water can take place outside the airports and the filing post, and runway will be arranged outside the regular airport (Franc, 2004). The final decision concerning the usage of the selected place will be up to pilot of the aircraft.

Because of the particular demands on such places, it is strongly advised to preliminary select the places for water supply, prepare documentation for these places and select the fire units for filling the aircraft with water. The documentation should contain:

- geolocation of the selected place,
- description of the access to the place by the roads,
- list of the selected fire units for water supply,
- nearest suitable water sources.

It is also strongly recommended carry out each year the exercise with units selected for water supply focused on filling the aircraft with water.

In the past, the documentation was prepared on the regional directorates of the Fire and Rescue Services in the form of printed card. The electronic version of the 150 cards was send in the form of Portable Document Format (pdf) or Office Open XML Document (docx) (Microsoft Word) to the General Directorate of the Fire and Rescue Services of the Czech Republic where they were manually processed into form of Office Open XML Workbook (xlsx) (Microsoft Excel table). Subsequently, the table was transformed into a form of map layer of ArcGIS for Desktop project and finally published as a service on ArcGIS Server.

Unfortunately, this process was not sustainable for a long time because of the necessity of regular update of the data in a short time and a limited amount of the person-days available. Because of that, it was decided to automatize the whole process of the update as much as possible.

#### 3.2 Automation of data collection

The first step in the process leading to the automation of the data collection and processing was a careful review of the existing card of the selected places for water supply.

After the review, the data model for selected places for water supply was formulated. The attributes were selected, and their allowed values were defined. The following attributes were selected as a crucial for description of the selected places for water supply:

- Name of the selected place.
- The starting sequence of the name of attachments concerning the given selected place.
- Address of the place.
- Type of the place (airfields of various types).
- Description of the place (near specification of the type of place).
- ICAO code of place (airfield) if is defined.
- VFR (Visual flight rules) book link if exists.
- Coordinates of the airfield in WGS84 coordinate system in decimal degree format.
- Owner of the place.
- The user of the place (can be different from the owner).
- Up to two contact person.
- Up to nine selected fire units for filling aircraft with water with the name of the units, standard abbreviation of its engine type and engine performance-related parameters.
- Up to four water sources.
- Up to four access routes.
- Warnings.
- Remarks.

By the above mentioned attributes, its allowed values were specified.

As a means for collecting the data from regional directorates of Fire and Rescue Service, the tables of Office Open XML Workbook (xlsx) (Microsoft Excel tables) were selected. They were defined as the simplest way to collect and process the data. The template of the table in Office Open XML Workbook was created. It contains the headers of the column and example record in the first row. The manual "how to fill the table" was also created.

In this manual, each step of filling the template table is described in detail. The manual gives the user detail information concerning the attributes in each column and the allowed and the example values. In the manual, the attachments, such as the original card describing the place in the form of Portable Document Format (pdf), the topographic map of the place and orthophoto image of the place, both as JPEG image are also described.

All the efforts were focused on the collecting of the set of Office Open XML Workbooks, each for one region, containing the attributes of selected places for water supply and set of the attachments for each selected place in the region.

#### 3.3 Processing of the data

The small Java program was created for processing the data sent by the regional directorates of Fire and Rescue Service. The main reason for creating the program, was an expectation, that during the data processing, the changes in original data

could occur (small corrections of the data, demands for adding new records to the data, ...) and it will be necessary to repeat the data processing correctly. Because it was expected, that the Java program for processing of the data will demand various libraries, the Java Apache Maven (Apache Maven, 2019) project was selected for creating the application for processing the collected regional data.

As a place for storing the data created by the application, the local installation of system PostGIS/PostgreSQL (PostGIS, 2019) was chosen because it enables easy storage of spatial data from Java programs and the stored data can be easily accessed and visualized in ArcGIS family programs. The local installation was chosen in order not to interfere with the workload caused by routine operation on the network-accessible databases in active duty.

Each critical step of the program was carefully logged both on to a screen and into a file with the Apache Log4j 2 logging framework (Apache Log4j, 2019). Logging was notably helpful in the case of program crash due to violation of prescribed data model in Office Open XML Workbooks.

After the program starts, it reads its configuration from an XML file and unmarshals it to the Java object with Java Architecture for XML Binding - JAXB (Jaxb, 2019). When the program configuration is read, the program starts the iteration through the Office Open XML Workbooks with data. It uses Apache POI (Apache POI, 2019) library for reading the Office Open XML Workbooks. Each row, which is not blank, in a workbook, excluding the first row with the heading of the columns, is transformed into an instance of the class containing the attributes of the selected place for water supply.

All the attachments obtained with the data are put on the webserver where there are available through standard HTTP protocol. The program uses the name of the attachment files to create a web link to the attachments on the webserver a store it into attributes. The application checks the links for the presence of the corresponding files to ensure the consistency of the data.

Because there is a necessity to have coordinates of the selected places in various formats, the other representation of the location than WGS84 decimal degrees are created. First, the WGS84 degrees, decimal minutes and degrees, minutes, and decimal seconds are counted. After that, the representation of the location in the national coordinate system S-JTSK is calculated. The ArcGIS Server service is used for coordinate transformation task. The usage of the national coordinate system S-JTSK is mandatory in the non-military information systems in the Czech Republic.

The unique attribute is created for storing the information if the selected place is active or not. The place can be sometimes unavailable for some reasons, like for example mowing the meadow or field.

The last step of data processing is the storage of the read and processed data into a spatial database. On the beginning of the storage process, the table in which data will be stored is dropped if exist and subsequently is freshly created the new empty table. To this table, the column for storing geometry is added. The table uses standard PostGIS geometry to store spatial data. For storing the data into a table, the java prepared

statement object is used to store data in an organized and fast way.

On the storage of the data, the process of publication of the data in the form of ArcGIS Server service follows. This makes the data available through to whole Fire and Rescue Service of the Czech Republic available to all authorized users.

The ArcGIS for Desktop project containing the layer with selected places for water supply is created. It also contains the symbology of the layer, which was created after the in-depth discussion with GIS specialists of regional directorates. Finally, the project containing the data is shared on the ArcGIS Server. Figure 4 shows the preview of the created service in the ArcGIS Online map viewer.

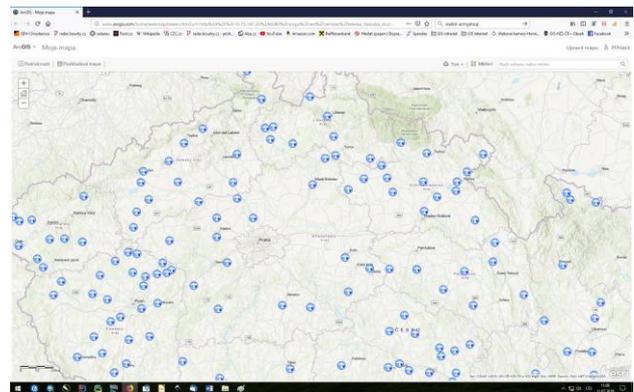


Figure 4. The preview of the created service of selected places for water supply in the ArcGIS Online map viewer.

#### 4. CONCLUSIONS

The forest fires and wildfires are a severe danger to the population, property, and environment. This threat is from year to year more serious, as is clearly illustrated in the maps based on the data concerning past emergencies.

The data concerning the emergencies, stored on the operational centers, are necessary background for the strategic decision of Fire and Rescue Service of the Czech Republic.

One of the vital tools in the fighting the forest fires, wildfires, and other large area fires is aerial firefighting. The essential prerequisite for its successful deployment is the organization of extinguishing media (mainly water) supply to the aircraft. For these purposes, the places for water supply are predefined and carefully documented. Such documentation must be available in the case of an emergency in a short time in an easily understandable manner to all persons involved in the management of the emergency.

Because of that, the article states the necessary attributes, which should be included in the documentation of selected places for water supply. It also describes the Java program for collecting and processing the data concerning the selected places for water supply.

The data describing the selected places for water supply is now available in the uniform and consistent manner as the ArcGIS Server service and can be used by the users and other programs

through the whole Fire and Rescue Service of the Czech Republic according to the actual need.

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