

AUTHOR'S INFORMATION ON DOCTORAL (PhD) THESIS

NATIONAL
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Council of Doctors

LÁSZLÓ BODNÁR

**Research and development of methods to increase the
effectiveness of firefighting in case of wildfires**

doctoral (PhD) thesis

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**Research and development of methods to increase the
effectiveness of firefighting in case of wildfires**

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Dissertation supervisor:

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DRAFTING OF THE SCIENTIFIC PROBLEM

Since humanity lived on earth, science has been constantly dealing with the dangers and their risks that affect us. Four of the five most likely risk factors today are related to climate change, so I consider the global climate change to be the basis of the scientific problem. Based on previous research and experiences, some trends can already be identified in relation to the climate change: the number of heat waves will increase as well as the number of hot days and nights. The change in the annual amount of precipitation will not be significant, but its distribution will already change significantly. We can expect a large decrease in precipitation in summer and autumn, and a more significant increase in precipitation in winter and spring. Based on the above, it is logical that the extreme phenomena of the weather will multiply. This means torrential rains in some areas, elsewhere, it means periods of permanent precipitation in space and time. Climate change is a challenge in many areas of science, society and life, so it also has an impact on the disaster management. The above mentioned climate change factors provide a greater opportunity to ignite the biomass, which increases the risk of wildfires. The wildland as a natural area carries many social values in itself, so the forest must be protected from the fires.

The relationship between the forest and society has noticeably changed in recent decades. As a result of urbanization, an urban sprawl can be observed on the one hand, and on the other hand a regular commuting from the agglomeration. The accelerated suburbanization contributed significantly to the merging of some settlements with the suburban environment, often abolishing the former classical boundaries. The increasing mobility is transforming city boundaries and bringing more urban areas closer to the forest. This gives a greater chance of human-caused wildfires. Fighting against forest fires is also driving today's opportunities in science and technology to increase the efficiency of protection. This calls for an analysis of new procedures and methods, such as the study of logistical difficulties during firefighting, the application of new technical tools or the study of fire prevention options in case of the populated area is close to the forest.

RESEARCH HYPOTHESES

After presenting the scientific problems and the research objectives, I set up the following hypotheses:

1. I assume that Wildland-Urban Interface areas have also developed in Hungary, where there is a significant risk of fire spreading from the natural environment to the residential environment.
2. In my opinion the establishment of protection zones can reduce the risk of the fire spread, which can make the personal and material protection of WUI areas more effective.
3. I assume that the logistical factors of firefighting have a significant impact on the efficiency of firefighting, which can be improved by maintaining and using the logistical reserves.
4. In my opinion a new firefighting technical tool can be used, which increases the extinguishing ability of firefighters while maintaining the free movement of firefighters, thus making the firefighting more effective.

OBJECTIVES OF THE RESEARCH

To investigate the fighting against wildfires and to achieve the scientific results of my PhD dissertation, I formulate the following research objectives.

I set a goal:

- to **identify the Hungarian Wildland-Urban Interface areas** and to **create** the first **map of Hungary showing the fire risk at Wildland-Urban Interface** with the help of exploring the current problems of the firefighting and the fire prevention of wildfires.
- to **propose new directives and legislations** to make the fire protection safer at Wildland-Urban Interface areas by creating protection zones.
- to **draw conclusions** from the logistical difficulties of fighting against wildfires, which are suitable on the one hand to show **the loss of the migration time**, and on the other hand to increase the efficiency of the water supply by establishing artificial reservoirs.
- to **point out the limitations of the load capacity of firefighters** and to **demonstrate the need of increasing the extinguish ability with free movement** and to propose the use of a new, innovative technical tool.

RESEARCH METHODS

In order to achieve my research goals and to prove my hypotheses, I used the following major research methods.

- I examined and analysed the scientific results of the relevant Hungarian and international literatures related to the topic, as well as the synthesis of the relevant research results of other authors.
- I made evaluative discussions and consultations with renowned Hungarian and international experts on the subject. During the discussions, I collected their comments and criticisms.
- In order to illustrate my scientific results, I made technical drawings and performed basic mathematical calculations.
- During the examination of the scientific problems, I used my own theoretical diagrams and performed image analysis on them.
- I made a SWOT analysis in connection with the location of the artificial reservoirs.
- Applying the principles of a systems approach, I made my own measurement in connection with the physical load of firefighters, during which I also used smart devices.
- I used logical conclusions and deductions, I analysed matrixes and created different models.

It is also a part of my research methods that during my doctoral training I compiled a study plan that established the scientific objectives of my research with the help of the subjects I chose. During the training, I systematized the knowledge I got during my previous studies and increased my professional competencies. In addition, I sought the opinions and practical experience of various experts on professional issues. I presented my results during the training at several Hungarian and international conferences. I also used this experience in my PhD dissertation.

A BRIEF DESCRIPTION OF THE PERFORMED EXAMINATION BY CHAPTER

In **Chapter I**, based on the most important literatures, I presented the combustion theory of the firefighting, the biotic, abiotic and agricultural factors in the generation of wildfires. In addition, based on relevant data, I analysed the global, the European and the Hungarian wildfire statistics. In addition, I determined the temporal and spatial characteristics of the generation of domestic fires. Then I summarized and identified the key conclusions from the statistics and made attention to the importance of the wildfires. Finally, based on my analysis of the literature, I identified the gaps in the Hungarian research of the topic.

In **Chapter II**, I examined the interaction between the natural environment and the built environment. Based on it, I identified the Wildland-Urban Interfaces (WUI) areas in Hungary and determined their county-level fire risk. In addition, I mapped the WUI areas, during which I also created a domestic topological matrix according to an international sample. Then, using my own new method, I also identified the Wildland-Urban Intermix areas. Finally, I proposed the establishment of protection zones in the WUI area.

In **Chapter III**, I examined the forest as a hard approachable area. I determined the logistical difficulties during the fighting against wildfires and performed an economic analysis in terms of the firefighting costs. I also examined the effectiveness of fire engines and technical equipment. Finally, I analysed some possibilities for the establishment of artificial reservoirs in terms of the efficiency of the water transport.

In **Chapter IV**, I examined new tools which can be effective during the firefighting. I formulated a proposal in the form of a so-called special firefighting frame structure (SFFS) that can also be used for firefighting purposes. I performed an efficiency test on the devices taking into account the individual economy criteria. In addition, I determined using my own measurement how the physical load affects to the interveners and the effectiveness of the firefighting. Pointing to the firefighting capabilities, I have demonstrated the need for new firefighting tools to increase the efficiency of firefighting.

SUMMARY CONCLUSIONS

I compiled my summary conclusions on the basis of the conclusions of each chapters, showing the stages of my research and the formulated conclusions.

In Chapter I, based on my analysis of the relevant international literature, I came to the conclusion that the international literatures use many new, foreign concepts that the Hungarian language has not used before (e.g. Wildland-Urban Interface). So, I considered it is necessary to explain these and to create new concepts on the topic.

Based on the examination of global, European and Hungarian wildfire statistics, I concluded that the number of forest fires does not change significantly at global level, compared to the previous years, but in many areas, where this kind of disaster was not a major challenge before, it has now become a current problem (e.g. Europe). As an analysis of the wildfire statistics in Hungary, I came to the conclusion that we can define two fire seasons in Hungary, such as the early spring and summer periods.

Based on the review of the Hungarian legal system, I concluded that in the field of the forest fire prevention, *the protection of WUI areas has not been developed yet*. From further examination of the literature, I found that the *costs of the wildfires* have been analysed before, these have not yet been *evaluated on a forint basis*, so it is a shortcoming within the topic. In terms of the cost-effectiveness firefighting, it has not yet been analysed *when and which vehicle or technical tool is the most effective* in case of wildfires. When analysing the logistic difficulties in case of firefighting, I found that although some research mentions the difficulty of the water transport, but they do not examine solutions such as the *establishment of artificial reservoirs*.

Firefighters use a huge number of technical tools during a wildfire. Although there are some analyses which examine the effectiveness of these, I have still found *reserves and development opportunities in the application possibilities of the tools* that can be involved in the firefighting against wildfires.

In addition, in Hungary has not yet been studied the amount of extra weight on firefighters due to the technical equipment during an intervention and the effect of it on the efficiency of the firefighting.

In Chapter II, I analysed the fire protection possibilities at Wildland-Urban Interface areas in Hungary. In order to overcome the language difficulties, I have created new concepts that fit the expectations of the profession and can enrich the vocabulary of the Hungarian language in the future. After studying international jargon, I created the Hungarian equivalents of the terms

Wildland-Urban Interface and **Wildland-Urban Intermix** (WUI mix), to which I apply the abbreviations of EKLA and ETLA.

After that, I identified the WUI areas in Hungary and proposed directives and legislative changes by creating protection zones. For the purpose of the research, I made technical drawings, applied mathematical calculations and also performed image analysis.

Based on my research, I came to the conclusion that there are some areas in Hungary that can be identified as WUI or even WUI mix. Due to the characteristics of the urbanization and the size and population of Hungary, I created my own model to identify WUI areas, based on a French risk analysis method. From the study of fire prevention at the WUI, as well as from my own calculations, I came to the conclusion that the areas near the residential buildings at the WUI can be divided into internal and external protection zones. The internal protection zone is the area of a circle with a radius of 10 meters around the residential building, which limit value is only relevant if the centre of the circle is the geometric centre of the residential building. In all other cases, the real shape of the internal zone is the polygons I have created, which are shaped by the protruding parts of the buildings. Based on the national study of the WUI, I determined the most endangered areas in Hungary. After further investigations of the WUI areas and in order to increase the efficiency of fire protection, I created the first Hungarian topological matrix from the study of foreign examples. This will help to identify the vulnerable WUI areas and help to take effective security measures. In addition, I created the first WUI vulnerability map of Hungary. As an extension and development of it, I created the map by analysing the biomass, the number of fires, and the characteristics of the residential areas.

In order to identify the WUI mix areas, I created my own new solution, which is based on the internationally accepted Radeloff method, however, the application of the method is simpler and does not require the use of complex GIS systems. From my research work above, I have come to the conclusion that my WUI and WUI mix results should be compared with the currently valid town planning plans. I found that the legislations in Hungary do not provide guidelines for preventing the spread of WUI fires, so I proposed a legislative amendment to fill this gap.

In Chapter III, I examined the logistical difficulties of firefighting. From the logistical difficulties of fighting against wildfires, I drew conclusions that are suitable for detecting the time loss of the migration and for establishing new methods and tools. Within this framework, I have dealt with the effects of the wasted time caused by migration on poor quality roads. I not only characterized the problem of the late arrival with the time, but **I related it to the increase**

in the length of the frontline of fire. To understand and illustrate this problem, I created a self-edited figure. Next, I analysed the advantages and disadvantages of a backpack water pump, a firefighting quad, a pick up, and a fire truck during the firefighting. By **comparing the efficiency of the tools**, I determined what types of interventions they can be used effectively. This was based on one of the most important factors in the efficiency of vehicles, the approach to the fire. Consequently, I have come to the conclusion that, as long as the damage site can be easily approached, the use of large and high-capacity vehicles is effective. However, this changes as we move towards to the interior of the forest, the smaller vehicles are more effective because of their good off-road capability. I consider the **forest pathway as a tipping point** in the efficiency of large and small vehicles. After the analysis, **I formulated a proposal for a new technical tool.**

Finally, I examined how to increase the efficiency of water transport by optimizing the establishment of artificial reservoirs. As a result of my **SWOT analysis**, I found that the advantages of using artificial reservoirs are the accessibility and the distance from the fire. As a result, I see the solution in an optimal location, for example along forest pathways or fuel breaks, which I have also verified by mathematical calculations. Then, as a result of my three-step analysis, I proposed the establishment of an artificial reservoir in the counties with water-scarce and highly flammable areas.

In Chapter IV, I examined a development option of a new technical tool. I pointed out the limitations of the load capacity of firefighters and proved the need to extend the ability to the firefighting with free movement. I also proposed the effective use of a new, innovative technical tool. For this, I used my results obtained during the examination of logistics problems, on the basis of which I determined that the last step of the migration logistics is the free movement of the firefighters with technical tools. However, it places an additional load on the firefighters. In order to be able to judge the effects of working with extra load, I conducted my own experiment to measure the work performance of a volunteer firefighting team. As a conclusion of my measurement, I stated that there is a need for a technical tool that allows to carry additional load and maintain free movement of firefighters at the same time. As a result, I determined the need for a technical device capable of using 100 litres of water without any physical usage. Using practical experiences and the measurements of other researchers, I created a cross-sectional model of the relationships between the frontline intensity of a fire, the amount of specific extinguishing agent, and the width of the wetted surface required for the safe firefighting. Then,

taking into account the amount of the available water capacity, I created a three-dimensional model that symbolizes the above mentioned values by using so-called boxes.

NEW SCIENTIFIC RESULTS AND THESIS

1. Using my own model, I identified the Hungarian Wildland-Urban Interface areas and determined the associated fire risks. As a result of the analysis of the Hungarian biomass, fire statistics and urbanization conditions, I created the first county-level WUI fire risk map of Hungary.
2. As a result of the fire protection solutions in case of WUI areas, I defined a zoning, where I created an optimal internal and external zone to reduce the risk of the fire spread. With the help of the protection zones, I made a proposal to modify the settlement planning conditions of Hungary, with the help of which the prevention of the fire spread from the forest to the residential area can become more effective.
3. Among the logistical factors of firefighting, I examined the effect of the time loss of migration on the efficiency of firefighting with a new approach. As a result, I determined the amount of time loss with a new method, which I first related to the increase of the fire frontline, and I proposed the optimal establishment of artificial reservoirs in water-scarcity counties with forest fire hazard.
4. With the limitations of the load capacity of firefighters, I proved the need to use a new firefighting technical tool that increases the extinguishing ability while maintaining the free movement of firefighters. I proved its effectiveness by creating a cross-sectional model and a box model.

RECOMMENDATIONS

During my four years of research, I have extensively examined the topic of wildfires. My research simultaneously touches the fields of fire protection, forestry, law and economics, as well as the technical and social science. Accordingly, I recommend the dissertation:

- to professionals and organizations responsible for the protection of wildfires and firefighting.
- to forestry authorities and forest owners who wish to contribute in some way to the development of the prevention of wildfires.

- to citizens who are in the forest area or in its immediate vicinity for permanent or recreational purposes.
- to professionals and economic organizations responsible for the development of research in the field of fire protection and firefighting
- to researchers, PhD students and university students who carry out their scientific work in the field of fire protection, firefighting and rescue control. My dissertation can serve as a basis for their studies.
- to fire chiefs, who have many wildfires in the operation area of their fire department.
- to legislators responsible for establishing and amending legislation in connection with the wildfires.
- to within the organization of the National Directorate General for Disaster Management, the specialists of the National Fire Department Inspectorate, the Fire Protection Department and the Firefighting Department.
- to the specialists of the Ministry of Agriculture who work in the professional field of forests and land affairs.

PRACTICAL USE POSSIBILITIES OF RESEARCH RESULTS

1. My research results on the examination of WUI areas provide an opportunity to make legislative amendments, since there is a need to prevent WUI and WUI mix fires in the flammable counties. The definition of the technical parameters of the internal and external protection zones around residential buildings can be included in the town planning and construction plans. In addition, at a later date, the protection zones can be included in Forest Fire Protection Plans.
2. In case of a wildfire, it is a great challenge to provide water for the firefighting and to determine how much water can be transported with the available firefighting tools and vehicles. As a result of the rule of thumb I have defined, it is easy to determine from the need of water which device has the highest water carrying capacity during the firefighting. As a result of my examination, I established that the difference between the maximum water carrying capacity of each vehicle is roughly three times.
3. My research results can be utilized in the field of the disaster management. The results of my dissertation can help researchers, PhD students and university students who carry out their scientific activities in the field of the firefighting, fire protection and rescue control.

4. In the process of developing technical tools for the disaster management, my suggestions can be taken into account, because in my research, I made a detailed efficiency study in case of some technical devices.
5. With the establishment of artificial reservoirs, the water supply of the firefighting can be more efficient in high fire risk and water-scarce counties. This is a great help in the field of fire protection, as the commuting route and time will also be shorter between the fire and the water source.
6. The use of the SFFS tool can be useful during the firefighting. By using the equipment, on the one hand, the amount of water that can be taken on the firefighter's back increases, and on the other hand, the physical load on the intervener can be reduced.

LIST OF AUTHOR'S PUBLICATIONS ON THIS SUBJECT

Revised book, application, note - Edited book article

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11. Bodnár László: Az erdőtűzek oltásának logisztikai problémái valós példák alapján. (*Logistic problems of fighting against forest fires based on real examples*) Bolyai Szemle, XXIV. évf. 4. sz. (2015), 86-99.o

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SCIENTIFIC BIOGRAPHY OF THE PHD CANDIDATE

László Bodnár was born on 31 of January 1992 in Budapest. He began his secondary school studies at the Dániel Berzsenyi Gymnasium in Budapest. After that, he first obtained a BSc degree in defence administration as a Defence Administration Organizer at the National University of Public Service, and in 2016 a MSc degree in defence administration as a Defence Administration Manager. He began his PhD studies in 2016 at the Doctoral School of Military Engineering at the National University of Public Service. Due to his full-time status, he regularly carried out teaching, organizing and research activities at the Department of Fire Protection and Rescue Control of the Institute of the Disaster Management of the Faculty of Law Enforcement. He is currently an administrator at the National Directorate General for Disaster Management, who works at the Institute of the Disaster Management of the Faculty of Law Enforcement.

Professional career

He participated in the teaching of the following subjects for a total of 120 hours at the Institute of the Disaster Management of the Faculty of Law Enforcement: Operational techniques of disaster management, History of profession, Innovative firefighting techniques, Writing Degree Thesis. He also provided an assistance to the Institute of the Disaster Management in its administrative and organizational tasks. Among other things, he was two times a court reporter at workshop discussions of doctoral dissertation draft and seven times at final exams. He also participated two times in the editing of conference books, as well as in the review and supervision of BSc thesis. In addition, he was four times a jury member of the Scientific Student Conference at the National University of Public Service.

Scientific competitions

In addition to the general competitions of the doctoral school, the Candidate also carried out activities related to other studies in connection with his topic. In 2017, he participated in the 2nd International Summer School on Disaster Management in Romania. He was a presenter at international conferences such as at the International Conference on Forest Fire Research in Portugal, the 8th Wood and Fire Safety Conference and the 23rd vedeckej konferencie s medzinárodnou účasťou Konferencia in Slovakia. He made shorter study trips under the ERASMUS + Program 2019 in Bloemfontein, South Africa and at the Fire Department of Berlin in Germany. In 2018, he successfully completed the short courses on fire safety and fire behaviour in Coimbra in Portugal.

Budapest, 10. December 2020

Bodnár László