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# The Use of 5G in Military Cloud of Things Solutions<sup>1</sup>

András TÓTH<sup>2</sup> 

In military operations, battlefield sensor systems and various solutions supporting reconnaissance and surveillance are increasingly important. Networked battlefield and military devices deployed in the operational theatre can be the best solution to this, ensuring that they are designed to collect all the data generated in their environment, which they are programmed to acquire. These devices continuously share the information they collect with each other and with a central storage and processing server. The required interconnections are typically two-way communications with all the criteria necessary to share the collected data in the shortest possible time. The data collected and analysed in this way can contribute significantly to the near real-time monitoring of the real operational situation and environment. This capability will enable the acquisition and maintenance of information superiority and can significantly speed up decision-making processes. Therefore, networked battlefield intelligent devices are essential for achieving operational objectives and successfully executing operations. In this paper, the author examines the integration of various levels of military IoT devices into the cloud environment and the use of 5G technology as a possible future solution for developing the communication environment. To achieve the research objectives, the author performs a comparative analysis between relevant international academic publications and technical reports on the topic, based on which he formulates his research results.

**Keywords:** Cloud of Battlefield Things, Cloud of Military Things, military 5G, network slicing

## Introduction

Digitalisation has a major impact on our everyday environment. Consequently, the European Union and its Member States have recently emphasised developing digitisation strategies and frameworks. Almost all these frameworks deal with developing smart cities, smart

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<sup>1</sup> This paper was supported by the János Bolyai Research Scholarship of the Hungarian Academy of Sciences and the ÚNKP-22-5-NKE-88 New National Excellence Program of the Ministry of Innovation and Technology.

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environments and ecosystems. In all of these, Internet of Things (IoT) devices and systems are inevitable, and through their widespread deployment, they have a major impact on our everyday lives. IoT devices constantly monitor their environment, collect data, and share it with other elements of the system and users according to their pre-programmed tasks. Since these devices collect much information from their environment, it is of paramount importance that this information is collected in a place with a large storage capacity and a sufficiently large computing capacity if needed. A cloud environment is the best solution for this. Hence, the combination of IoT and cloud computing is called the Cloud of Things (CoT). These tools appear in the civilian environment and are also increasingly used in military operations, where they can support soldiers in tracking the operational situation in real time and help make decisions as quickly as possible. In this context, some publications have been published in the past year describing the basic requirements<sup>3</sup> and possible solutions<sup>4</sup> for using IoT devices in military environments. IoT devices used in military environments are called the Internet of Battlefield Things (IoBT) or the Internet of Military Things (IoMT), depending on the operational environment and level. If these devices are connected to the cloud environment, we can talk about Cloud of Battlefield Things (CoBT) or Cloud of Military Things (CoMT) solutions.

## Research contributions

After defining the basic concepts of this paper, the author presents the theoretical possibility of linking 5G and IoT devices in military operational environments. To do so, the author seeks answers to the following research questions:

- Can 5G technology provide the right communications connectivity for cloud-based interconnection of IoT devices on the battlefield?
- Can 5G private radio networks be used in military networks?
- What are the biggest security challenges in the use of military 5G?

To answer these questions, the author has examined the characteristics of 5G technology and its applicability in military communication environments. To achieve the Cloud of Things transmission requirements, he examined the possibilities of 5G deployment.

## The conceptual framework of the Cloud of Battlefield Things and the Cloud of Military Things

To understand the concepts of the Cloud of Battlefield Things and the Cloud of Military Things, it is first necessary to clarify the difference between the Internet of Battlefield

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<sup>3</sup> Csaba Kollár: Az IoT katonai felhasználási lehetőségei és a fejlesztés irányjai. *Hadmérnök*, 12, no. 4 (2017). 146–158.

<sup>4</sup> Eszter Katalin Bognár: Possibilities and Security Challenges of Using IoT for Military Purposes. *Hadmérnök*, 13, no. 3 (2018). 378–390.

Things and the Internet of Military Things. The IoBT is a set of devices that use two-way communication with each other and can transmit operational battlefield data, information, and situational awareness to other devices and share it in near real-time using some technology (databases, file sharing, cloud-based systems) to support decision-making at the tactical level. In contrast, the IoMT is a higher-level solution, where information is not only available from the battlefield but also from a much more extensive set of assets. Strategic assets such as long-range unmanned aerial vehicles (UAVs), reconnaissance aircraft and satellites with various cameras are also deployed. Accordingly, the IoMT is a set of devices and systems that use two-way communication with each other, which can transmit strategic data, information and operational situational awareness generated during their operation to other devices and share it in near real-time using some technology (databases, file sharing, cloud-based systems) to support strategic decision-making.

It can be seen from the above that, as stated in the introduction, the basic purpose of IoT tools in an operational environment is to provide real operational situational awareness and support decision-making processes. Therefore, an extremely large amount of data is required, which must always be available in the right place, time and format. Cloud computing is an excellent solution for this. There is enough storage space in a cloud environment to store the large amount of data collected, and the high computing capacity helps analyse data quickly. It is the most optimal solution for connecting widely used IoT devices. In a military environment, the integration of battlefield IoT devices into a cloud environment is called the Cloud of Battlefield Things. A CoBT is a system that integrates networked battlefield assets into a common cloud environment to make the collected battlefield information available to authorised personnel at the appropriate time, place and format to provide a real-time operational situational picture. The system can thereby contribute to the acquisition of information superiority, thus helping the successful execution of operations. The strategic-level system is called the Cloud of Military Things, a system that integrates networked military devices into a common cloud environment to make the collected information available to authorised personnel at the appropriate time, place and format to provide a real-time operational situational picture at all levels of the operation. The system can thereby contribute to the acquisition of information superiority, thus helping the successful execution of operations.

The CoMT and the CoBT have a layered architecture, and the focus of this article is on the communication solutions between the layers. The conceptual structure of the layers is illustrated in Figure 1, where the first layer contains the different sensing devices (sensors, sonars, cameras, radars), the second layer is the cloud layer itself, where the storage and computing capacities are located, and the third layer is the access layer, where users access the information stored in the cloud through applications. Finally, the cloud layer contains the cloud layer of CoBT, which in the case of CoMT is the Multi-access Edge Computing solution.

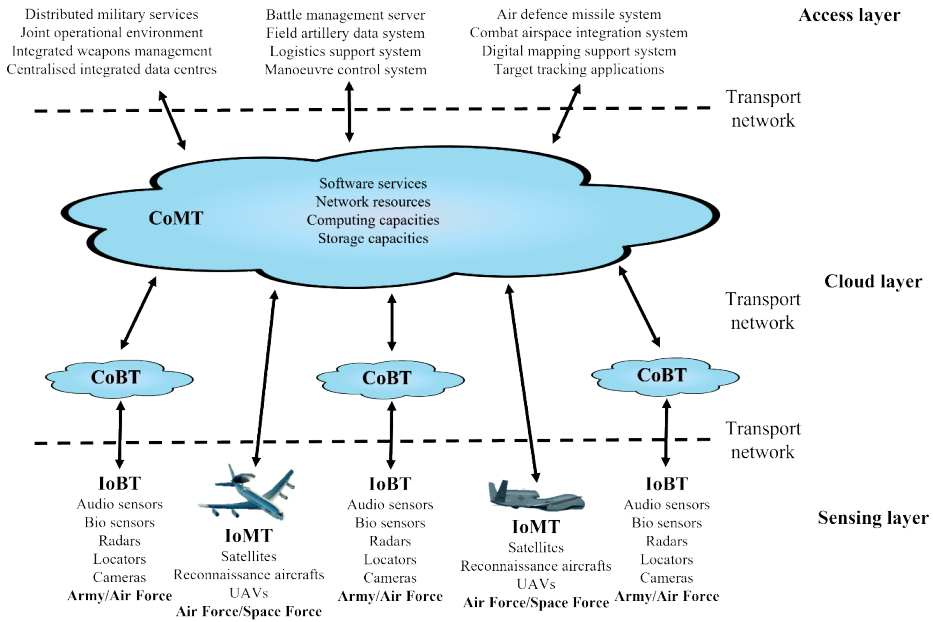


Figure 1: Layered architecture of the Cloud of Military Things

Source: Compiled by the author.

Immediate information sharing is very important in military applications, so the use of low latency systems, where the key is to process information at a nearby point, is of utmost importance. In the case of IoMT, this is made possible by the Multi-access Edge Computing (MEC) solution used in IoBT, which is an autonomous processing unit at the edge of the network. This solution is an essential element of 5G-based infrastructures such as transport infrastructure, where low latency is essential (self-driving cars, unexpected traffic information, etc.), where the data is processed directly by the radio access network (RAN) without any intervention from the central system in the MEC so that only the aggregated data is provided to the central network (in this case the CoMT).<sup>5</sup>

## Characteristics of 5G networks

5G wireless technology aims to deliver high data speeds, reliability, availability, ultra-low latency, massive network capacity and a more consistent user experience for more users than in previous generations of technology. The performance of 5G networks should be assessed using three parameters: user bandwidth, device density and latency. The International Telecommunication Union (ITU) has set requirements for the minimum

<sup>5</sup> Abderrahime Filali et al.: Multi-Access Edge Computing: A Survey. *IEEE Access*, 8 (2020). 197017–197046.



values of these parameters in Recommendation ITU-R M.2083-0. This Recommendation sets out the framework and overall objectives for international mobile telecommunications (IMT) for 2020 and beyond, the framework for its future development, including a wide range of capabilities related to the intended use scenarios, and further development of existing capabilities of IMT and the development of IMT-2020. In addition, it identifies eight core areas for the capabilities, each of which has developed a target to support the development of 5G capabilities. These parameters and goals are illustrated in Table 1.

Table 1: IMT-2020 development goals

Key capabilities	Parameters	Aims
Peak data rate	Maximum data transfer rate per user/device (in Gbit/s) achievable under ideal conditions.	1 Gbit/s → 20 Gbit/s
User experienced data rate	Data rate (Mbit/s or Gbit/s) available to the mobile user/device everywhere in the coverage area.	10 Mbit/s → 100 Mbit/s
Spectrum efficiency	Average data throughput per unit of spectrum resource and per cell (bits/s/Hz).	1x → 3x
Mobility	A maximum achievable speed (in km/h) to ensure a specified QoS and seamless transmission between radio nodes, which may belong to different layers and/or radio access technologies (multilayer/RAT).	350 km/h → 500 km/h
Latency	The contribution of the radio network to the time (in ms) between the packet sent by the source and the packet received by the destination.	10 ms → 1 ms
Connection density	Total number of connected and/or accessible devices per unit area (per km <sup>2</sup> ).	10 <sup>5</sup> → 10 <sup>6</sup> devices/km <sup>2</sup>
Network energy efficiency	Energy efficiency has two aspects: on the network side, energy efficiency refers to the number of bits of information transmitted to and received from users per unit of energy consumption (in bits/Joule) of the radio access network (RAN) on the device side, the energy efficiency refers to the amount of information bits per unit of energy consumption of the communication module (in bits/Joule)	1x → 100x
Area traffic capacity	Total traffic throughput served per geographical area (in Mbps/m <sup>2</sup> ).	0.1 Mbps/m <sup>2</sup> → 10 Mbps/m <sup>2</sup>

Source: ITU-R (2020): *op. cit.*

The table illustrates the key objectives that the International Telecommunication Union has identified as a priority for the development of 5G. These objectives can also contribute greatly to developing communications capabilities currently used in the military environment. 5G offers several capabilities that can benefit military networks, especially tactical networks, such as manageability, dynamic spectrum management, ample bandwidth and low latency. The standards framework developed by the 3<sup>rd</sup> Generation Partnership Project<sup>6</sup> (3GPP) provides a good basis for this, setting out the basic requirements needed to

<sup>6</sup> A collaborative project of a group of telecommunications associations whose original aim is to develop globally applicable specifications for third generation (3G) mobile systems.

build 5G systems and networks. However, this development is subject to different phases, of which Release 17 was frozen in March 2022. Thus, the framework and requirements set out therein will be enforceable for all 5G networks, and devices and systems used in military environments will be able to comply with the triangle of requirements set out in ITM-2020. The adaptation of these requirements to the military environment is illustrated in Figure 2.

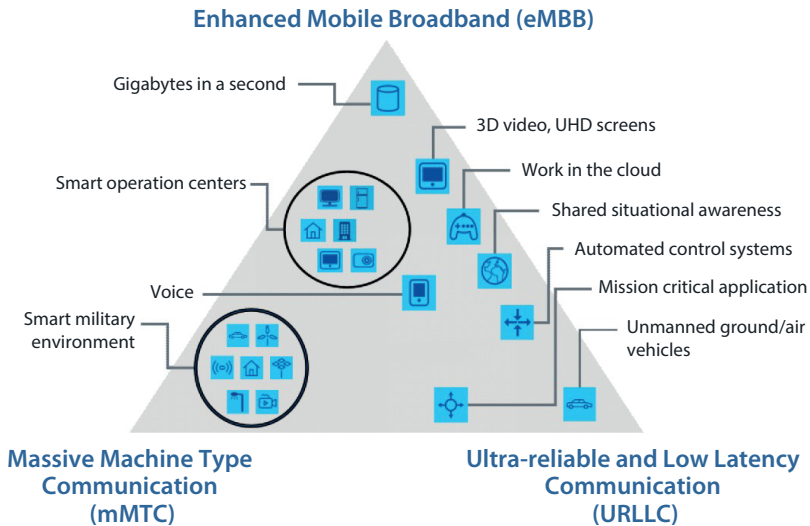


Figure 2: Triangle of requirements for the military 5G system

Source: ITU-R (2020): *op. cit.*

Some characteristics of the elements defined in the triangle of requirements are:

- Enhanced mobile broadband (eMBB): this typically covers people centric IMT services with high traffic bandwidth, high user density, and low to medium mobility needs. Its basic function is to provide fixed wireless access (FWA) in areas without wired access (this is essentially the case for operational areas).
- Massive machine type communications (mMTC): these communication services are targeted at Internet of Things (IoT) applications that use many connected devices with poor radio connectivity that require low throughput but high data transfer capability over time.
- Ultra-reliable and low latency communications (uRLLC): this communication service provides low throughput but also provides low latency and high availability data services for applications that do not require high throughput but need high connectivity in a mobile environment. Application examples include near real-time human–machine (or machine–machine) interfaces such as remote control or automatic/semi-automatic (weapon) control systems.<sup>7</sup>

<sup>7</sup> Luis Bastos et al.: Potential of 5G Technologies for Military Application. 2021 *International Conference on Military Communication and Information Systems (ICMCIS)*, (2021). 1–8.

These capabilities mean that 5G can handle – and interconnect – much more data than previous systems, can be used in a much wider range of applications (including a broad spectrum of military operations), and is much more complex, making security a much bigger issue than before. To achieve these, the following systems engineering objectives must be met:

- flat network architecture
- separation of the control plane and the data plane
- all functions in a self-contained unit – support for cloud computing
- optimal resource utilisation – network slicing
- high-level coordination

## **The use of 5G in the Cloud of Battlefield Things and the Cloud of Military Things**

The architecture of 5G systems is defined by a reference model developed in 2018 for the 3GPP Release 15 framework. The 5G system architecture consists of, among others, the following network functions (NF):

- 5G Next Generation NodeB (5G gNB)
- Access and Mobility Management Function (AMF)
- Authentication Server Function (AUSF)
- Centralized Unit (CU)
- Data Network (DN)
- Distributed Unit (DU)
- Network Exposure Function (NEF)
- Network Repository Function (NRF)
- Network Slice Selection Function (NSSF)
- New Radio (NR)
- Policy Control Function (PCF)
- Radio Access Network (RAN)
- Session Management Function (SMF)
- Unified Data Management (UDM)
- User Equipment (UE)
- User Plane Function (UPF)

The relationships between the elements are defined by the following reference points in the 5G system architecture:

- N1: Reference point between the User Equipment and the Access and Mobility Management Function.
- N2: Reference point between the Radio Access Network and the Access and Mobility Management Function.
- N3: Reference point between the Radio Access Network and the User Plane Function.
- N4: Reference point between the Session Management Function and the User Plane Function.

- N6: Reference point between the User Plane Function and a Data Network.
- N9: Reference point between two User Plane Functions.<sup>8</sup>

The above elements are typical of 5G networks and systems, and therefore, if they are deployed in a military environment, the same elements will be present. However, what is necessary for the security of military networks is partial or complete isolation from public networks. The primary reason for this is security, but it is also important to be independent and to ensure that military networks function properly in the event of the failure of a public system element. 5G private networks and network slicing provide solutions to this. In the case of private networks, some elements may still reside on the public network (for example, the Access and Mobility Management Function), but with network slicing, the private network manages the entire data plane, so data generated and stored there cannot be leaked from the internal network. In addition, the system used must be standalone (SA). This solution will provide the above requirements, enable the full 5G capacities (eMMB, uRLLC, mMTC), and provide a significantly more flexible architecture and dynamic interconnection of network functions. In the SA configuration, the 5G network is built with dedicated equipment and network functions, 5G radios are coupled with cloud-native, service-based core network functions, and these network functions are fully virtualised and cloud-native. Figure 3 shows the conceptual architecture of an isolated military 5G network, where the standalone elements of the network are completely physically and logically separated from the public network.

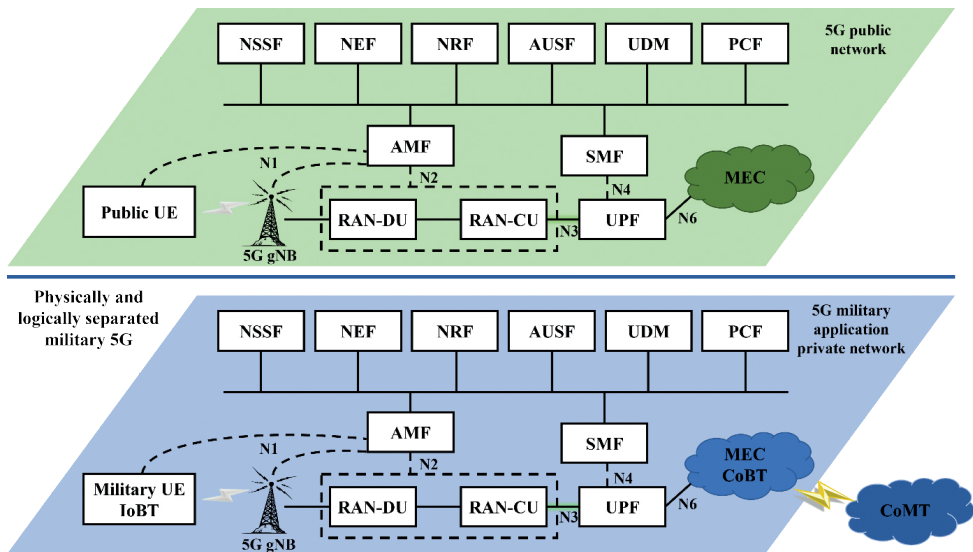


Figure 3: Triangle of requirements for the military 5G system

Source: Liao–Ou (2020): *op. cit.*

<sup>8</sup> ETSI: 5G; System Architecture for the 5G System (3GPP TS 23.501 version 15.3.0 Release 15). 2020.

As shown in the figure above, an independent private network has been created for the military application, where both the control plane and the user plane are isolated from the public network. Accordingly, the frequency bands used in the military environment are also different from the public one, so it can be completely independent from the service providers. This configuration guarantees absolute data security for military applications as it is completely isolated from the public network. In addition, both the core network and the wireless access network can be deployed on combat platforms, with short round-trip data transmission distances and low network latency. Finally, this solution ensures that military user devices (IoBT) can be connected to the control plane via non-terrestrial networks (NTN). Following Release 17, NTN-based eMBB and massive IoT services will be supported by NR, Narrowband-Internet of Things (NB-IoT) and LTE for Machine Type Communication (LTE-M) solutions, which provide reliable and bandwidth-adequate wireless connectivity for IoBT devices. Communication between devices can be done directly through the Access and Mobility Management Function, but typically this is done through some 5G gNB<sup>9</sup> node that connects IoBT elements to the user plane. Interconnections are managed by the Radio Access Network, where devices integrated into the network are connected to distributed units, which are interconnected and managed by the centralised unit. The collected data is then sent to the User Plane Function and subsequently to the Multi-access Edge Computing autonomous processing unit. All activities that support real-time monitoring of the operational situational picture, operations planning and decision-making occur here. In the resulting system, 5G, with the software-defined radios and MIMO technology used, can realise the data transmission requirements between IoBT devices and cloud technology.

## ***Network slicing***

For 5G networks, network slicing technology is available to enable the logical and physical separation of network resources to ensure the customisation, separation, and support of services and multi-tenancy on common physical network infrastructure. The technology provides a flexible way to facilitate multi-tenancy, greater network coverage, and a reliable solution for infrastructure and cloud service providers. Network slicing can be set up on an on-demand or permanent status, dedicated to a specific person or group, or to separate different services. The fundamental goal of the 5G ecosystem is to support full mobility and continuous availability in all conditions. Accordingly, it is perfectly suited for use in military environments. Therefore, the 5G technology with network slicing provides the following capabilities:

- Enhanced broadband access everywhere: providing high bandwidth access throughout the entire territory of operation, ensuring the connectivity of the end devices located in the whole area.

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<sup>9</sup> The 5G base station uses new radio (NR) technology and is called gNodeB (gNb). The gNodeB radios have software-defined radio (SDR), such as Massive MIMO (multiple-input and multiple-output) options for higher capacity.

- High user mobility: providing broadband support for fast-moving vehicles, for example to support connectivity for military convoys on the move.
- Massive Internet of Things: supports broadband access to extremely dense networks of sensors and actuators, considering among others long-range and low-power devices.
- Extreme real-time communication: providing ultra-low latency connectivity, for example for IoBT devices.
- Extremely reliable communication: provide extremely low latency, reliable and available network connectivity to support, for example, autonomous weapon systems.
- Mission-critical communications: supports connectivity in the event of disasters and emergencies and has the flexibility to handle sudden increases in traffic while providing resilient connectivity.
- Broadcaster-like service: providing network connectivity to any service that supports, for example, the delivery of patches sent to firmware updates or fix security vulnerabilities.
- Easy communication: provides a network connection for generating, configuring, and maintaining basic service information.
- Multiple connectivity: provides network connectivity to deployed and operated smart devices using multiple access technologies.<sup>10</sup>

As seen above, network slicing for 5G is a solution that enables the creation of logical networks on a common infrastructure with appropriate isolation, resources and optimised topology to serve a predefined use case. In their paper,<sup>11</sup> the authors describe the different implementation options and ways of network slicing, based on which Figure 4 illustrates one of the possible 5G technology designs for military environments.

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<sup>10</sup> Ibrahim Afolabi et al.: Network Slicing and Softwarization: A Survey on Principles, Enabling Technologies, and Solutions. *IEEE Communications Surveys & Tutorials*, 20, no. 3 (2018). 2429–2453.

<sup>11</sup> Akihiro Nakao et al.: End-to-end Network Slicing for 5G Mobile Networks. *Journal of Information Processing*, 25 (2017). 153–163.



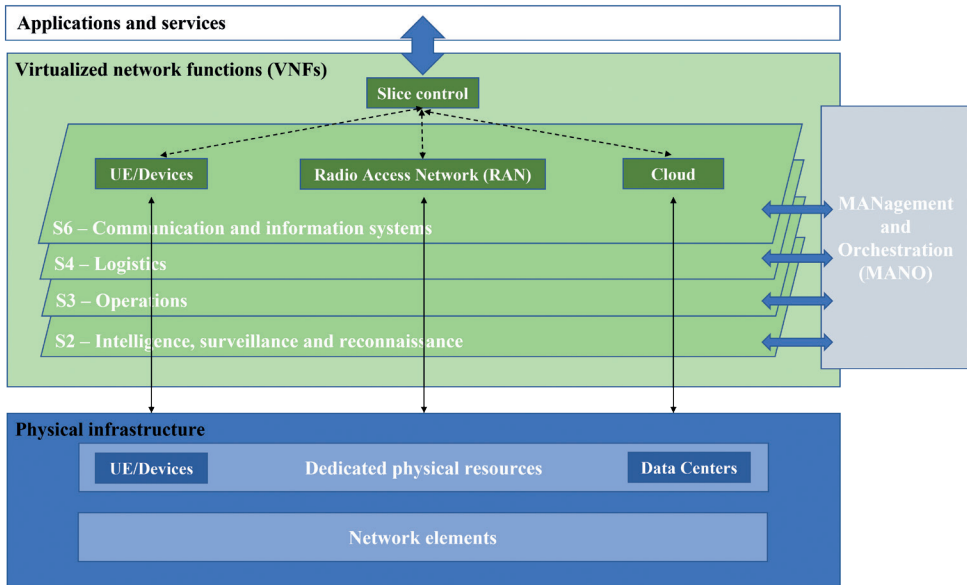


Figure 4: Network slicing in military 5G

Source: Nakao et al. (2017): op. cit.

In case of 5G systems used in military networks, separating segments and tasks can be the basis for network slicing. In this case, the different sections each use a separate virtualised network. The services running here are the virtualised network functions (VNF), which are managed and administered by the management and orchestration (MANO), which is a key component of the network functions virtualisation (NFV) architecture. The NFV is the service that enables 5G network slicing, allowing different virtual networks to run on a single physical infrastructure. In addition, it allows the partitioning of a physical network into virtual networks capable of supporting multiple radio access networks.

### Satellite communication

The data processed and stored in the CoBT can also be delivered to the CoMT over 5G networks, but different communication solutions are typically used due to their large scale. 5G non-terrestrial networks extend the reach of 5G NR technology and its associated benefits to non-terrestrial platforms. The on-air 5G NR architecture will enable mobile network operators to provide 5G-based services in locations where terrestrial networks are unavailable, or longer distances need to be covered. These solutions provide the required services without any intermediate protocol or technology changes. 5G NTN can be provided by satellites, High Altitude Platform Stations (HAPS), or any

other aircraft capable of carrying the NTN payload.<sup>12</sup> Focusing on the convergence of satellite and terrestrial networks, the authors<sup>13</sup> have presented different implementation options for satellite-terrestrial networks, such as generic, software-defined network (SDN), information-centric network (ICN), content delivery networks (CDN), based satellite-terrestrial networks. Figure 5 illustrates the conceptual possibility of 5G satellite interconnection of CoMT.

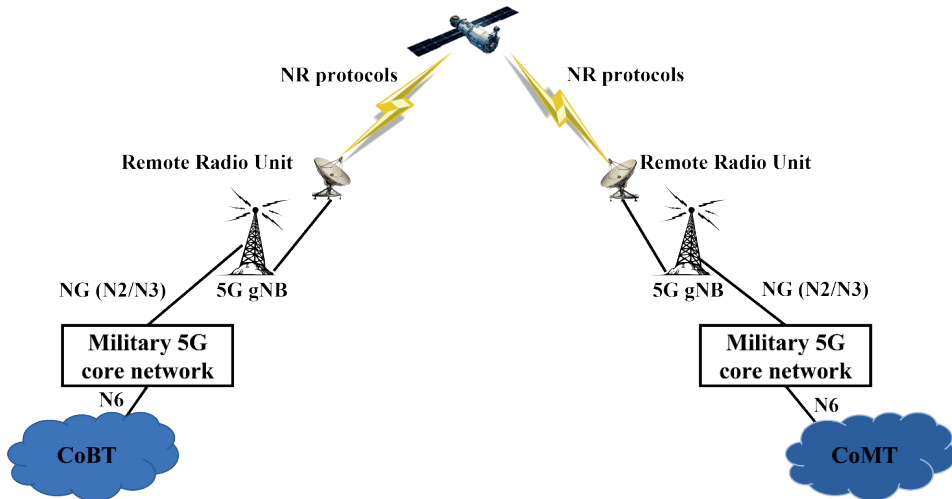


Figure 5: 3GPP military 5G satellite communication architectures

Source: Wang et al. (2020): op. cit.

## 5G Security issues in the Cloud of Battlefield Things and Cloud of Military Things

5G networks deployed in CoBT environments have many useful features described above but also present several security challenges. Ensuring adequate security is also a big issue for IoT devices used in military operations. From an operational safety point of view, it is of paramount importance to guarantee the safety of the equipment or systems used because if the equipment or systems used are damaged, it can seriously impact the whole operation and even endanger the lives of several soldiers. For CoBT, it is not only the user devices that are a problem, but vulnerabilities or threats can occur at all levels of the system that can have a negative impact on operations. The authors describe these risks in

<sup>12</sup> Bastos et al. (2021): op. cit.

<sup>13</sup> Peng Wang et al.: Convergence of Satellite and Terrestrial Networks: A Comprehensive Survey. *IEEE Access*, 8 (2020). 5550–5588.

their article<sup>14</sup> for civilian use, and the transfer of these risks to a military environment is illustrated in Table 2.

Table 2: Threats and vulnerabilities in Cloud of Battlefield Things and Cloud of Military Things

Domain	Threats
Military UE (IoBT)	Firmware issues Malware Botnet Device tempering Device capture
RAN	Jamming DDos Node damaging Rogue base station Man-in-the middle attack
Edge and core network	SDN, MEC platform vulnerabilities DDoS Eavesdropping Spoof attack Man-in-the middle attack 3 <sup>rd</sup> party application
Service	Unidentified and unauthorised access Service hijacking Abusing cloud computing Insecure or compromising interfaces and API Data leakage and breaches Key compromise and the breakage of cryptographic protocols

Source: Kim (2020): *op. cit.*

To ensure adequate security, developing an information security CIA triad is a basic requirement for both CoBT and CoMT. Accordingly, the system and network developed must have the appropriate confidentiality, integrity and availability capabilities.

Confidentiality means preventing unauthorised persons from reading or accessing sensitive material. This security aspect hides information by encrypting the payload to a significant level. In the design, there should be a strong emphasis on the fact that obfuscation of information entering, leaving and passing through the CoBT and CoMT system is a critical requirement. This will prevent information from being exposed to intrusion and eavesdropping attacks.

The manipulation and destruction of data to mislead the parties involved in the communication constitute a breach of integrity. Like confidentiality, integrity is a widely discussed concept in information security. Moreover, integrity plays a key role in the context of CoBT and CoMT, as the services hosted there are typically automated, and accurate information is required for the efficient operation of autonomous services.

<sup>14</sup> Hwankuk Kim: 5G Core Network Security Issues and Attack Classification from Network Protocol Perspective. *Journal of Internet Services and Information Security (JISIS)*, 10 (2020). 1–15.

Availability means that CoBT and CoMT resources are available everywhere for customers who want to use the services. This factor depends primarily on network performance and the efficiency of network interfaces. Therefore, the performance of the designed network is of paramount importance for CoBT and CoMT.<sup>15</sup>

In addition to these, in their article<sup>16</sup> Sicari et al. also specify other important factors that must be guaranteed for the safety of the systems designed:

- non-repudiation
- authentication methods
- access control
- data protection of information and devices
- trust between 5G network components and end-users
- compliance with specific security and privacy policies

## Conclusions

New types of private sector communications technologies and information services solutions offer opportunities for military applications that can make a major contribution to the successful conduct of military operations. For example, integrating IoT devices, which are becoming more widespread in the military environment, into the cloud can provide a real operational situational awareness to gain and maintain information superiority, contributing to the successful execution of operations. A very good basis for this is the isolated 5G technology presented in this article, which guarantees absolute security of data for military applications, as it allows military networks to be completely isolated from public networks. The author has thus obtained a positive answer to his first research question since 5G technology can be used to develop a robust, reliable, high-bandwidth system with low network latency that can be deployed on various combat platforms. Furthermore, with a private 5G network, high mobility, trusted and secured connections can be established to support battle command and control management and various support activities. As a result, the author also received a positive answer to the second question, but for private networks it should be highlighted that their deployment is associated with high deployment costs and a very heavy workload for the operating staff. Network slicing can be an excellent solution, where a separate 5G private network does not need to be established. However, a logical layer can be created by virtualising the existing public network to provide a more appropriate environment for military operations. Into this virtualised network, battlefield and military IoT devices can be integrated and deployed into a cloud infrastructure. The designed system will meet all the requirements of any technical solution deployed in an operational environment.

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<sup>15</sup> Pasika Ranaweera et al.: Survey on Multi-Access Edge Computing Security and Privacy. *IEEE Communications Surveys & Tutorials*, 23, no. 2 (2021). 1078–1124.

<sup>16</sup> Sabrina Sicari et al.: 5G in the Internet of Things Era: An Overview on Security and Privacy Challenges. *Computer Networks*, 179 (2020).

All in all, the author has successfully identified the fundamental security challenges for some segments of 5G technology in military environments, which could seriously impact the overall system operation. In a previous article,<sup>17</sup> the author has already made suggestions for securing Cloud of Things solutions, where he presented technical and technological solutions that can greatly contribute to building and maintaining a secure network in a military cloud environment.

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# Complex Analysis of Wildfires in Hungary in the Last Decade<sup>1</sup>

László BODNÁR<sup>2</sup> – Péter DEBRECENI<sup>3</sup>

*Wildfires are one of the most common natural disasters in the world, which cause millions of hectares of damage each year. This fact poses a major challenge to the defence sector. Environmental safety problems caused by wildfires affect not only the ecosystem but also all aspects of society. Research on the effects of climate change predicts a more uneven rainfall distribution and rising daily average temperatures in summer and autumn in the Carpathian Basin. The effects of climate change will be indirectly detectable, such as the extension of fire risk periods, the increase in the number of wildfires and their spatial and temporal distribution, and the increase in fire intensity. Changes due to climate change will pose an even greater challenge in the future to the Hungarian authorities, which are responsible for preventing and extinguishing wildfires. One of the purposes of the paper is to define indicators that can be used to compare the number and extent of wildfires each year with the degree of the daily fire risk and the length of periods during which the wildfires occurred. For this, it is necessary to define the concept of the high fire risk days and the endangered areas and parts of the country in the Hungarian climatic conditions. Based on previous statistical studies, the authors will examine the spring and summer fire seasons separately because of the different fuel conditions and the causes of fire ignition. They examine statistical data on wildfires and apply GIS application. Another aim of the research is to find a correlation between the daily fire risk values, the number of wildfires and the burned area. A fire risk-based investigation of the wildfires that have occurred in the last decade can later help in official preparation, annual planning and preparation of forces involved in the prevention and firefighting.*

**Keywords:** wildfire, statistics, fire weather index (FWI), fire risk, raster, trends and changes of forest fire danger

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## Introduction

Ever since humanity has lived on Earth, science has been constantly dealing with the dangers and the risks that affect us. At different periods of history, different risk factors came into view. According to the Global Risks 2020 report of the World Economic Forum (WEF), four of the five most likely risk factors of today are related to climate change.<sup>4</sup> These include the failure to combat climate change, the loss of biodiversity, the frequent occurrence of extreme weather, and the risk of major natural disasters.<sup>5</sup> Long-term forecasts agree on certain things, such as drought and warming, however, not in terms of scale and seasonal as well as regional differences. In this case, we can already discover many differences in the scenarios.<sup>6</sup> Global climate change scenarios predict a rise in temperature of 1.1–6.4°C by the end of the 21<sup>st</sup> century. In addition, it is to be expected that the frequency of heat waves as well as heavy rainfall may increase further. Based on research and experience, some trends can already be identified about climate change: cold days will become less frequent, the number of cold mornings will become less and less, in contrast, heat waves will increase and the number of hot days and nights will increase.<sup>7</sup>

The study of global climate scenarios is also relevant in Europe. In Hungary, the regional climate scenario of the Carpathian Basin is the most cited research result. In the research of Bartholy et al., the period 2071–2100 was examined. With the help of the models they made, they were able to predict the temperature increase more accurately than the expected change in precipitation. Regarding the warming, the study of the summer months is more interesting, as warming is the largest at this time (3.7–5.1°C), as well as the most significant variance is also here. According to the study, the standard deviation will be the lowest in spring, estimated at only 2.4–3.2°C. During the summer season, the warming rate will increase in the southern parts of the country, and in winter and spring, moving eastwards.<sup>5</sup> In addition, the number of heat days, when the temperature reaches or exceeds 30°C ( $T_{max} \geq 30^\circ\text{C}$ ) will increase by 109–156%. The number of hot days – when the temperature reaches or exceeds 35°C – will increase ( $T_{max} \geq 35^\circ\text{C}$ ) from 4 days per year to 20–33 days. In contrast, the number of winters ( $T_{max} < 0^\circ\text{C}$ ) and frosty ( $T_{min} < 0^\circ\text{C}$ ) days will decrease and the number of harsh days ( $T_{min} < -10^\circ\text{C}$ ) will decrease significantly (from –87 to –95%) annually.

The climate of the Carpathian Basin will also be significantly affected by changes in precipitation distribution. According to the scenarios, the change in the annual amount of precipitation will not be significant, but its distribution will already change. We can expect a more significant decrease in precipitation in summer and autumn (10–33%). In winter and spring, a more significant increase in precipitation is expected. Furthermore,

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<sup>4</sup> World Economic Forum: *The Global Risks Report 2020*.

<sup>5</sup> Ivett Szászi: *Globális kockázatok 2019* [Global Risks in 2019].

<sup>6</sup> Judit Bartholy et al.: A 21. század végén várható éghajlatváltozás Magyarországon [Regional Climate Change Expected in Hungary by the End of the 21<sup>st</sup> Century]. *Földrajzi Értesítő*, 56, no. 3 (2007). 147–167.

<sup>7</sup> IPCC 2007: *Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, Cambridge University Press.

the number of days with annual extreme rainfall ( $\geq 20$  mm) may double in the future.<sup>8</sup> One of the consequences of global climate change is that extreme weather extremes are multiplying. As a result, the chances of heavy rainfall and thunderstorms are increasing in some parts of the Carpathian Basin. However, in other areas, the lack of precipitation periods will be extended in space and time.<sup>9</sup> During the drier months, the moisture content of the fuel decreases, thereby increasing its combustibility, and it gives a higher risk of fire ignition. One of the consequences of climate change is the increased risk of forest fires.

Analysing the climate scenarios about forest fires, it was found that even with an increase in the average temperature of 0.5 degrees in Hungary, the frequency of vegetation fires can increase by more than 50%.<sup>10</sup>

According to other scenarios, an increase in the average temperature of 4°C may increase the frequency of forest fires by up to 200 to 300%.<sup>11</sup> This will pose a continuing challenge to disaster management in the future.<sup>12</sup> Forests are one of the most important natural resources. For this reason, the fire protection activities of the disaster management are appreciated. In the event of damage or destruction of forest property by fire, there are high costs.<sup>13</sup> The effectiveness of forest fire prevention activities may affect the functioning of the environmental, economic and social sectors, and has an impact on the quality of life of the population living near the forest.

## Fire prevention system in Hungary

Forest fire prevention activities are carried out in close cooperation with the disaster management agency and the forestry authority. Not only the European Union,<sup>14</sup> but also

<sup>8</sup> Judit Bartholy – Rita Pongrácz: Regionális éghajlatváltozás elemzése a Kárpát-medence térségére [Analysis of Regional Climate Change in the Carpathian Basin]. In Zsolt Harnos – László Csete (eds.): *Klímaá változás: környezet – kockázat – társadalom* [Climate Change: Environment – Risk – Society]. Budapest, Szaktudás Kiadó Ház, 2008.

<sup>9</sup> Sándor Szalai – Péter Vigh: *Új térképek és adatok a klímaá változás trendjéről* [New Maps and Data on the Trend of Climate Change]. Előadás, Klímaá változás és az erdők [Lecture, Climate Change and Forests]. Budapest, Erdészeti Fórum, 2005.

<sup>10</sup> IPCC Report: *IPCC jelentés: Éghajlatá változási Kormányközi Testület Tematikus jelentése a szélsőséges éghajlati események kockázatairól és kezeléséről* [Special Report on Managing the Risk of Extreme Events and Disasters to Advance Climate Change Adaptation]. Döntéshozói Összefoglaló. Budapest, Nemzeti Fejlesztési Minisztérium, 2011.

<sup>11</sup> János Mika: A globális felmelegedés regionális sajátosságai a Kárpát-medencében [Regional Features of Global Warming in the Carpathian Basin]. *Időjárás*, 92, nos. 2–3 (1988). 178–189.

<sup>12</sup> Attila Bussay et al.: *Az aszály magyarországi előfordulásainak vizsgálata és mérhetősége* [Investigation and Measurability of Drought in Hungary]. Budapest, Országos Meteorológiai Szolgálat, 1999; László Teknős: Current Issues in Disaster Management Aspects of Global Climate Change. In László Földi – Hajnalka Hegedűs (eds.): *Effects of Global Climate Change and Improvement of Adaptation Especially in the Public Service Area*. Budapest, Dialóg Campus, 2019. 145–162.

<sup>13</sup> Ágoston Restás: Common Analysis of the Costs and Effectiveness of Extinguishing Materials and Aerial Firefighting. In Domingos X. Viegas – Luís M. Ribeiro (eds.): *Advances in Forest Fire Research*. Coimbra, Universidade de Coimbra, 2014. 1799–1813.

<sup>14</sup> Regulation (EC) No 2152/2003 of the European Parliament and of the Council of 17 November 2003 concerning monitoring of forests and environmental interactions in the Community (Forest Focus).

the Hungarian legislation<sup>15</sup> requires the authorities to plan forest fire protection activities. The aim of it is the coordinated development and implementation of forest fire prevention activities. In addition, modern firefighting knowledge and the tasks of organisations involved in forest fire prevention have also been incorporated into the Hungarian legislation.

The basis of the forest fire prevention activity is the recording of forest fire events on forest land and other wooded land areas. By analysing forest fires in the register, we can gain knowledge about the characteristics of fires and the course of the fire season. Over the past two decades, the methodology and rules for data collection and analysis have been developed through the cooperation of the forestry authority and disaster management. IT systems for data collection and analysis have been set up by the responsible authorities. The register shall be kept by the provisions of the Ministerial Decree on the protection of forests against fire.<sup>16</sup> The regulation also regulates the activities necessary to prevent forest fires. It lays down the rules for ordering a fire ban also. The decree defines the criteria for the fire hazard classification of forest areas and the rules for the preparation of forest fire protection plans. The regulation provides a formal framework for cooperation between the forestry authority and disaster management. The regulation also sets out the prevention tasks for forest managers. These include the construction and maintenance of fire and fuel breaks, placing warning signs during a fire ban, constructing and maintaining fire pits, and the availability of various firefighting technical tools. The authority shall assist in the implementation of the forest management obligations. It prepares educational materials and organises training for foresters and farmers. Leaflets, issues and handbooks are freely available on the authority's website.<sup>17</sup>

The rules for fighting against forest fires (tactics, reconnaissance, intervention, safety regulations, mop-up) are contained in the sectoral legislation of disaster management. The rules for controlling fire protection are spelled out in the Fire Protection Act. The detailed rules of intervention are set out in the Law on Protection against Fire and its implementing regulations.<sup>18</sup>

The forest fire data are evaluated and sent to the European Forest Fire Information System (EFFIS) each year by the forestry authority. The EFFIS was established jointly by the European Commission (EC) services Joint Research Centre (JRC) and Directorate General for Environment in the year 2000 to support the national services in charge of the protection of forests against fires in the EU and neighbouring countries, and also to provide the EC services and the European Parliament with up-to-date and harmonised information on forest fires in Europe. EFFIS is the largest repository of information on individual fire events in Europe. The database is supported by the European Expert Group on Forest Fires. The author of this article is also a member of the expert group delegated by NÉBIH.<sup>19</sup> The database implements the exchange of information between member states.

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<sup>15</sup> 4/2008 (VIII.1.) Decree of the Ministry of Local Government on the protection of forests against fire.

<sup>16</sup> Ibid.

<sup>17</sup> FireLife Forest Fire Prevention Project.

<sup>18</sup> Act XXXI of 1996 on the Protection Against Fire, Rescue Work and the Fire Service; Decree 39/2011 (XI.15.) of the Minister of the Interior on general rules of fire safety and technical rescue operations of fire brigades; Recommendation No 6/2016 (VI.14.) of the Fire Tactics Regulations and Technical Rescue Regulations.

<sup>19</sup> For more information see <https://effis.jrc.ec.europa.eu/partners>

Member States and the EU Commission can assess the impact of measures taken to protect forests against fires. EFFIS provides data on the development of strategies for protecting forest fires, with a special emphasis on knowing the cause of the fire.<sup>20</sup>

On the European level, the fire situation is that the risk of forest fires has increased in the southern regions in the last two decades, but an increase in the number and extent of forest fires should also be expected in the Nordic countries. Currently, 85% of burned areas in Europe are located in Southern Europe (Portugal, Spain, France, Italy and Greece) due to the higher risk of weather conditions typical of the Mediterranean region. In these five Mediterranean countries, an average of almost half a million hectares of land has burned annually over the past 20 years. In addition to the increase in the annual number of high and extreme fire risk days, the impact of extreme fires will likely increase in large areas, with long-term effects. The forest fire season starts earlier and ends later, which puts an additional burden on disaster management agencies. Forestry and fire ecology research prove that, among the abiotic forest damages, forest fires can be effectively prevented in the short term with forestry methods and awareness-raising campaigns.<sup>21</sup>

In the next section, we present the fire situation in Hungary. To prepare the statistics, data recorded in the forest fire information system between 2011 and 2021 were used.

## Presentation of the fire situation in Hungary

When recording fire data, fires are divided into four categories according to the type of site.<sup>22</sup> Courtyard of facilities means when a fire occurs on a property bordered by a fence in an indoor area, affecting vegetation. The most common case is when a fire breaks out in the yard of an apartment building or farmstead. The next class is the burning of household waste or garbage on the outskirts. The main target objects of EFFIS are forest fires, although also other wildfires are recorded. For the database forest fires are defined as uncontrolled wildfires spreading wholly or in part on forest and/or other wooded land. Thus, to be classified as a forest fire, the uncontrolled fire has to affect partially or totally, though not exclusively, forest and/or other wooded land and it does not necessarily have to start in a forest.

In the study, we examined those wildfires, where firefighting intervention was required. In case of events requiring an intervention, on-site data collection will take place. Figure 1 shows the number of fires in the examined period between 2011–2020 in the type of sites. 62% of all fires were wildfires in the examined period, firefighters intervened in 96% of these fires. In some years, compared to the ten-year average, there were quite a few fires (2013, 2016), while in other years there was a number of wildfires above the average (2012, 2022). The primary reason for this is the amount of precipitation and its distribution over

<sup>20</sup> Camia Andrea et al.: *The European Fire Database. Technical Specifications and Data Submission*. JRC Science and Policy Reports, 2014.

<sup>21</sup> Péter Debreceni et al.: Az erdőtüz kockázatának csökkentési lehetőségei Magyarországon [Methods of Forest Fire Risk Reduction in Hungary]. *Védelem Tudomány*, 2, no. 2 (2017). 1–11.

<sup>22</sup> 6/2014 (III.7.) BM OKF instruction on the data provision procedure for firefighting and technical rescue activities of disaster management bodies and fire departments.

time. In 99% of cases, wildfires in Hungary are caused by human negligence or intent. This rate is a few percent higher than in the countries of the Mediterranean region (95%), where the natural origin of fires is also not uncommon.



Figure 1: Total number of fire events in the type of sites between 2011–2021

Source: Compiled by the authors based on the database of the National Directorate General for Disaster Management, Ministry of the Interior, the National Food Chain Safety Office and the Forest Fire Information System.

Table 1: Total number of wildfires between 2011–2021

Year	Wildfires (including forest fires)		Forest fires	
	Number of fires	Burned areas (ha)	Number of fires	Burned areas (ha)
2011	8,436	24,662	2,021	8,056
2012	15,794	90,668	2,657	14,115
2013	4,424	8,020	761	1,955
2014	5,535	25,140	1,042	4,454
2015	5,057	14,938	1,069	4,730
2016	2,531	3,414	452	974
2017	6,782	13,761	1,454	4,934
2018	2,981	3,016	530	906
2019	7,296	13,922	2,088	6,541
2020	4,339	6,230	1,239	2,895
2021	4,350	6,038	1,154	2,413

Source: Compiled by the authors based on the data of the National Food Chain Safety Office and the Forest Fire Information System.



Table 1 shows the total number of wildfires that occurred between 2011–2021, highlighting the number of fires and the burned areas. Wildfires typically burn outside residential areas on natural grasslands, forest land and other wooded land. Forest fires are defined as uncontrolled wildfires spreading wholly or in part on forest and/or other wooded lands.

The average number of wildfires was 6,139 in the examined period. In case of forest fires, the average number of fires is 1,315 and the average burned area is 4,725 hectares. Studying the high number of fires, it is important to note that these fires were caused by violations of fire regulations. According to the current regulations, the incineration of vegetation in the open air is fundamentally prohibited.<sup>23</sup> At least 10 days before the combustion of dead fuel, a notification must be made to the disaster management. Combustions in connection with forest management must be reported to the disaster management at least 48 hours before the start of it. One indicator of the severity of a wildfire is the size of the burned areas. Examining the size of the burned areas during a fire, we divided the fires into nine groups. A fire of less than one hectare is considered a small fire. Fires between 1 and 50 hectares can be classified as medium and wildfires of more than 50 hectares are considered large fires. In case of medium and large fires, several fire services may be alarmed, taking into account the risk factors. For all wildfires, the area affected by forest fires in the examined period averaged 3.2 hectares. Analysing the data in Table 2, it can be determined that the proportion of small fires has been increasing constantly. It has exceeded 60% in every year since 2012 and 70% since 2018.

*Table 2: The proportion of wildfires in classes of burned area*

Classification of burned area	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
0–0.1 ha	33.8	36.8	41.7	36.2	37.8	40.5	35.1	37.7	40.1	44.9	61.5
0.1–0.5 ha	9.2	10.4	10.1	10.7	12.1	9.3	13.8	20.2	15.5	15.7	14.6
0.5–1 ha	15.2	14.3	15.8	14.1	12.9	15.7	14.2	14.5	15.2	14.3	11.1
1–5 ha	28.7	24.4	24.2	25.0	24.8	27.2	23.9	20.2	18.5	16.1	9.3
5–10 ha	7.2	6.6	5.0	6.1	6.1	4.0	6.3	5.3	5.3	4.7	1.9
10–50 ha	4.7	6.1	2.8	6.8	5.1	3.1	6.1	2.1	4.7	4.1	1.4
50–100 ha	0.8	0.8	0.4	0.6	0.8	0.2	0.6	0.0	0.5	0.2	0.1
100–500 ha	0.2	0.7	0.1	0.5	0.4	0.0	0.1	0.0	0.3	0.1	0.1
More than 500 ha	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

*Source: Compiled by the authors based on the data of the National Food Chain Safety Office and the Forest Fire Information System.*

Figure 2 shows that the number of forest fires below 0.5 ha has increased in the last decade. In particular, the increase in the number of so-called point fires below 1,000 m<sup>2</sup> is significant. The number of forest fires between 1–5 ha was reduced. The number of fires larger than 10 hectares has not changed in the last decade.

<sup>23</sup> 54/2014 Decree of the Ministry of the Interior on the National Fire Regulation.

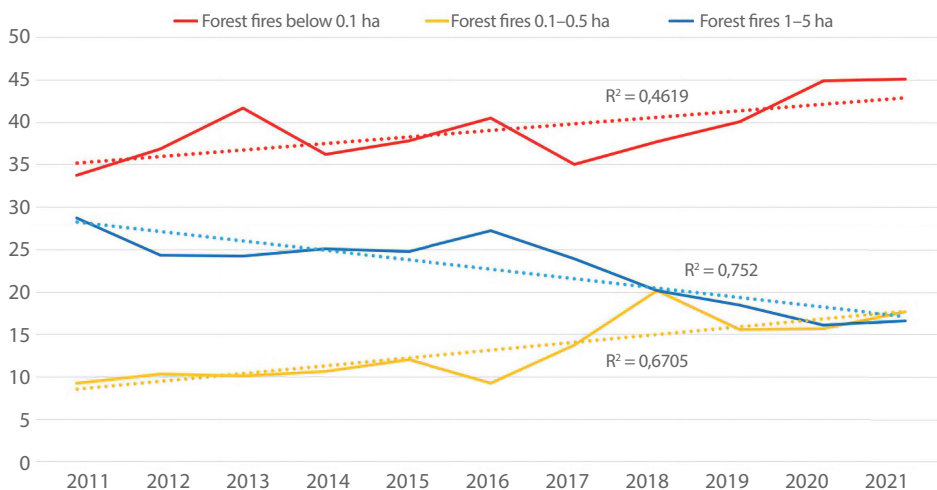


Figure 2: The proportion of forest fire events within classes of burned areas between 2011–2021

Source: Compiled by the authors based on the data of the National Food Chain Safety Office and the Forest Fire Information System.

Examining the fires in non-wooded areas shows an even stronger trend in the case of point fires. To examine the reasons behind the unfavourable trend, it will also be necessary to know the factors influencing the fire risk (meteorological conditions, surface cover and topographic conditions).

Based on the date of wildfires, two high fire risk periods can be distinguished during the fire season (Figure 4). Spring forest fires (February–May) accounted for 56.3% of the total number of forest fire cases. In the last decade, only in the spring of 2013 has there been significant rainfall, with hardly a few fires. In the other years, there were high fire risk periods in March and April. During this period, the rate of wildfires was above 50% in six springs compared to the annual number of fire events. At the beginning of this decade, the number of forest fires began to increase at the end of February, and high numbers of fire cases were registered by the end of April. The length of the high fire risk period in spring has depended on the distribution of spring precipitation. This trend has begun to change by the end of this decade. Due to the extreme droughts of the last three years, the number of forest fires started to rise from the second week of February and we recorded extremely high fire numbers until the end of April. In May and the first half of June, depending on the rainfall distribution, the fire risk decreases and we do not see any outliers in the number of recorded wildfires.

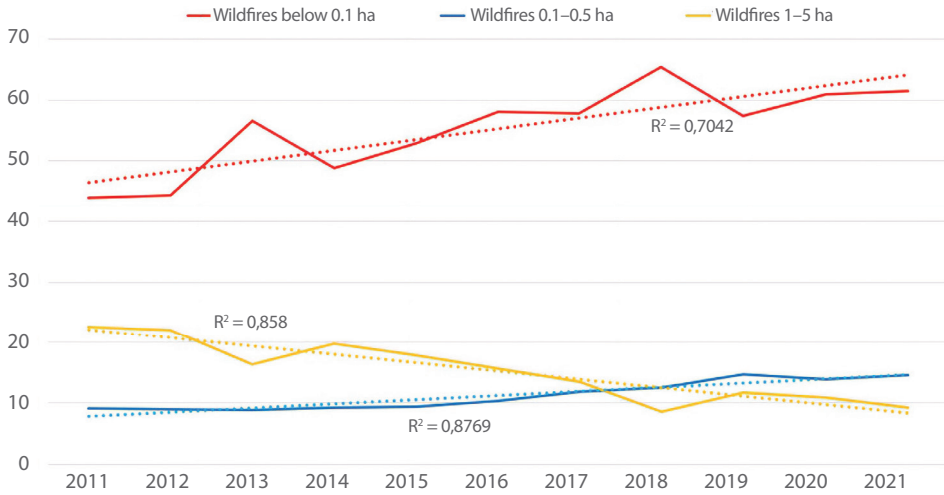


Figure 3: The proportion of wildfire events within classes of burned areas between 2011–2021

Source: Compiled by the authors based on the data of the National Food Chain Safety Office and the Forest Fire Information System.

Based on the number of wildfires, the second high-risk period of the year is in July and August. In the second half of the last decade, a lack of precipitation also developed in September and October. Some large fires also occurred in the autumn period, which is an unusual phenomenon in Hungary. In recent years, due to the summer drought, several large-scale crown fires have developed in the lowland pine forests and also in the forest and shrubs of the northern part of the country. The increasing number of fires shows that due to climate change, fires brake out as early as at the beginning of the year, unlike in previous decades. Over the next decade, there could be more firefighter interventions in the spring period.

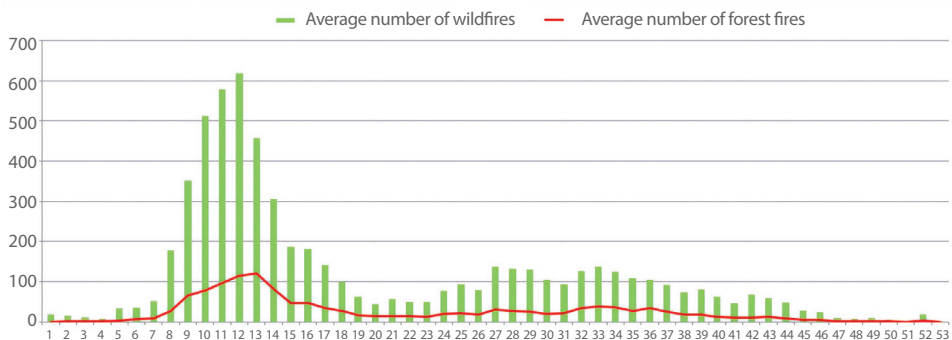


Figure 4: Average number of wildfires and forest fires per week between 2011–2021

Source: Compiled by the authors based on the data of the National Food Chain Safety Office and the Forest Fire Information System.

As shown in Figure 5, it can be stated that based on the number of fires and the burned areas, the most endangered parts of Hungary are Bács-Kiskun, Borsod-Abaúj-Zemplén, Heves, Nógrád, Pest and Szabolcs-Szatmár counties.

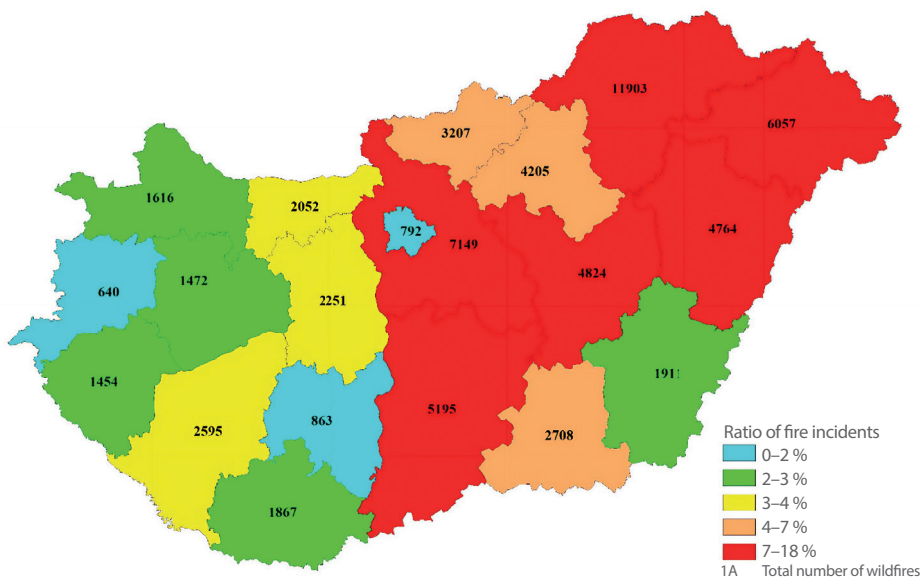


Figure 5: Total number and ratio of wildfires in counties between 2011–2021

Source: Compiled by the authors based on the data of the National Food Chain Safety Office and the Forest Fire Information System.

In the last decade, 45.1% of spring fires occur in the Northern Hungary region (Borsod-Abaúj-Zemplén, Heves, Nógrád) and Pest county. It refers to the high vulnerability of

Borsod-Abaúj-Zemplén county; 20.8% of the spring wildfires and 25.5% of the burned areas were in this region.

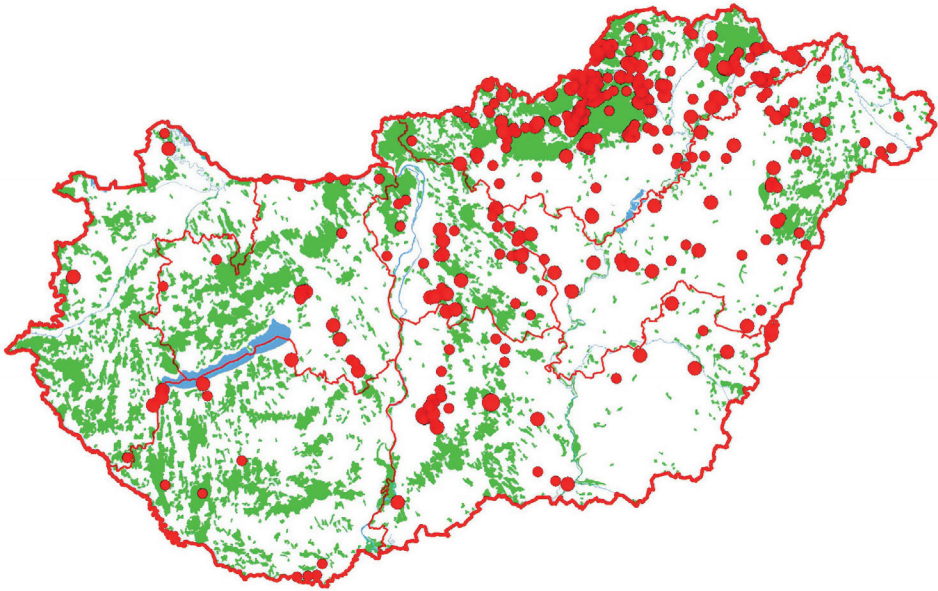


Figure 6: Wildfires larger than 50 hectares in the spring period (2011–2021)

Source: Compiled by the authors based on the data of the National Food Chain Safety Office and the Forest Fire Information System.

56.7% of the wildfires in summer occur in the Great Plain region, where crown fires can also break out. During the summer, 103 large-scale wildfires exceeding 50 hectares were registered. 60.8% of these also occur in the pine areas of the Great Plain region. In Hungary due to climatic conditions and the composition of the fuel, only 1% of all wildfires break out by natural causes. Most causes of the fires are human negligence or intent. According to the national fire database, these can be cigarettes discarded from cars or trains, neglected campfires, careless burns, or poorly organised barbecues.

## Legislative background for the definition of high fire risk periods in Hungary

Fire bans that can be ordered in case of high fire risk periods are already covered by Act LIV of 1996 on Forests and the Protection of Forests.<sup>24</sup> During this time, the Minister of Agriculture ordered a general fire ban in case of high fire risk periods. The ban was issued in the Hungarian Official Gazette. Forest fire prevention rules have also been incorporated

<sup>24</sup> Act LIV of 1996 on Forests and the Protection of Forests (repealed).

into Act XXXVII of 2009 on forests, on the protection and management of forests<sup>25</sup> (Forest Act). Between 2009 and 2017, the law ordered the promulgation and revocation of the total fire ban in a ministerial decree. A significant change from the previous regulation was that from that date not only the responsible Minister for forestry but also the forest authority could order a fire ban in its jurisdiction area – in consultation with the County Disaster Management Directorate – at the county or municipality level. During this period, a general fire ban was announced at the county level. Based on the amendment of the Act in 2017, the order of announcement of the fire ban has changed. From this date, the high fire risk period is announced for the entire country or county or local level. The Minister responsible for forestry ensures the determination of the high fire risk period and informs the public with the involvement of the National Directorate General for Disaster Management and the Ministry of the Interior (NDGDM). The determination and revocation of the high fire risk period depend on meteorological conditions, the drought of living and dead fuel on the forest floor, and the frequency of fires. According to the Forest Act, in case of a high fire risk period, it is forbidden to light fire in the forestland and its outskirts area within 200 metres. A fire ban is also valid if the competent authority has not imposed a fire ban, but the high fire risk area has been identified. In addition to the Forest Act, other legislation in connection with the ignition in wildlands also links the prohibition measures to the high fire risk periods.

## **An overview of the application of wildfire indicators on the EU level**

Fire risk depends on the combined effect of several factors such as climatic conditions, vertical and horizontal structure of the vegetation, moisture content of the dead biomass, forest management methods, forest fire prevention activities and socio-economic conditions. Large-scale wildfires occurred in the world due to extreme weather conditions. However, most of the fires can lead back to human activity.

On hot, dry days, such weather conditions can develop fire outbreaks. This can increase the number of areas, where fires can break out and extend the fire season. The number of fires and burnt area indicators can characterise high fire risk regions over a longer period. So in countries where long-term datasets are available, these data are used as indicators to characterise the main processes.

Based on the forecast of international and domestic climate research, the number of heat and summer days is expected to increase. At the same time, the number of rainy days decreases, and the risk of drought increases. Rainy periods shift to autumn and winter, which increases the chances of spring and summer fires. It is a feature of almost every European country that much of the fire can be traced back to human intervention. In addition, meteorological conditions and combustible fuels also play a crucial role in the development of fire hazards. In Europe, the correlations between the fire risk periods of the last three decades and the fires have been examined with the Canadian Forest Fire

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<sup>25</sup> Act XXXVII of 2009 on forests, on the protection and management of forests.



Weather Index (FWI) used by the EFFIS. Research by the European Environment Agency notes that the wildfire risk of Hungary was similar to northern Spain and Greece, but by the end of the century, it would increase to the same level as the Mediterranean region.

The increase in fire risk will result in more and more extremes in the distribution of precipitation. A lot of rainfall in a short period can cause serious damage to areas affected by wildfires, which endangers forest regeneration. Analysing the data of the EFFIS, it was determined three high fire risk periods that can occur in the European Union. In winter, wildfires burn in mountainous regions, in spring in Northern and Central Europe, and in areas associated with summer droughts. Processes over the last 30 years have been examined using the Canadian Forest Fire Weather Index, which is based on a daily fire risk calculation. The special indicator derived from the model is the so-called Seasonal Severity Rating (SSR). This is a dimensionless value, so it is possible to compare fire risk over time and space between years and regions. SSR showed a significant increase in many regions of Europe between 1981 and 2010.<sup>26</sup>

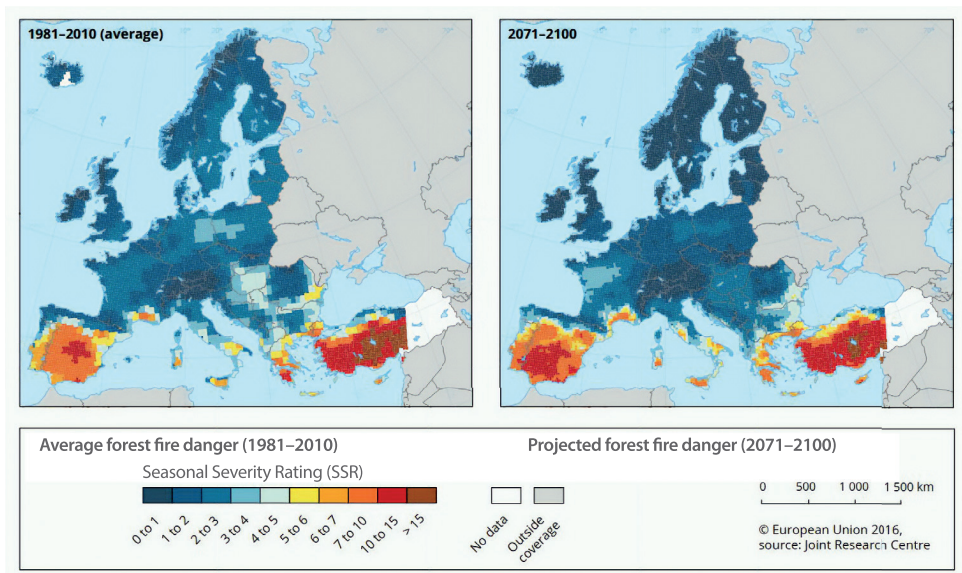


Figure 7: Development of fire risk in the European Union between 1981–2000 and the change predicted by the models for the period between 2071–2100

Source: European Environmental Agency.

Based on forecasts, the length of fire risk periods is expected to increase. As a result of it, wildfires may start in February and also even in October. As Figure 2 and Figure 3 have shown, an increase in the number of small fires has been demonstrated over the past decade. Fire intensity and the rate of spread can increase on high fire risk days, increasing the size

<sup>26</sup> EEA Report No 15/2017: *Climate change adaptation and disaster risk reduction in Europe. Enhancing coherence of the knowledge base, policies and practices.*

of the burned area and making it more difficult to control the fire during firefighting. Studies on the effects of climate change predict significant warming, heat waves and longer dry periods, mainly in the Mediterranean region and in Central Europe, including Hungary. The length and impact of the fire seasons can increase, and risk areas and the risk of large-scale fires and desertification in these areas may also increase in the future.

The scenario shown in Figure 8 predicts that in the next 30 years the size of the burned area in one fire season, the risk of large-scale fires and the emission of greenhouse gases will increase in Hungary.<sup>27</sup> In the Central and Northern regions of Europe, the risk of fire and the area affected by the fire will also increase due to rising temperatures. An increase in the fire potential is also forecast in Hungary compared to the period between 1961–1990. Given the expected increase in fire risk, it will be important in the future to investigate anthropogenic impacts on the spatial distribution of fire and land use habits. Consequently, a fire risk assessment will be a daily task inevitably in the future. In the next part, some indicators will be examined that can show the differences between consecutive years on the country level.

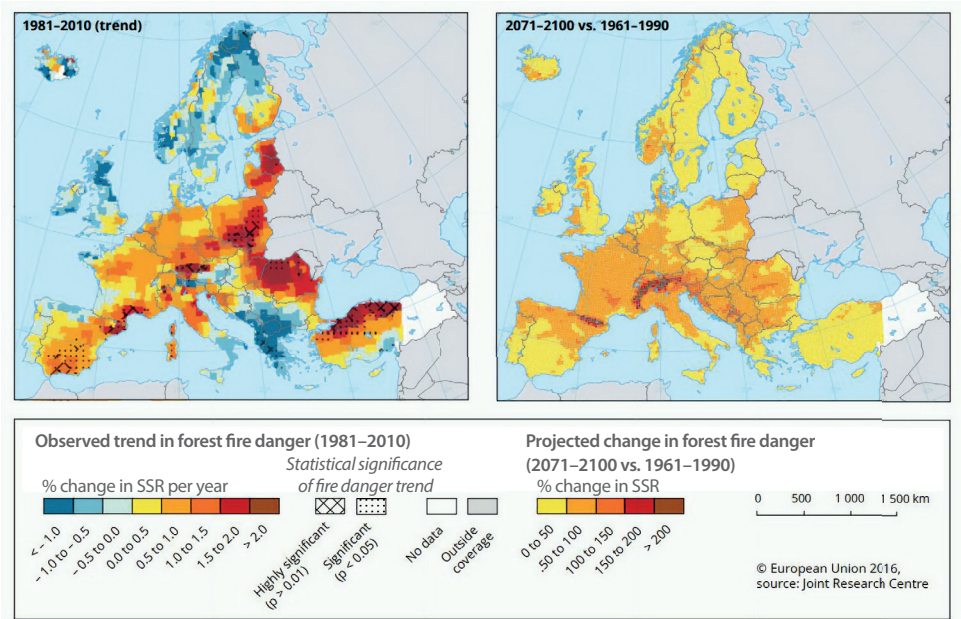


Figure 8: Change in the trend of fire hazard between 1981–2000 and change compared to the period between 2071–2100

Source: European Environmental Agency.

<sup>27</sup> EEA Report No 1/2017: *Climate change, impacts and vulnerability in Europe 2016. An indicator-based report.*



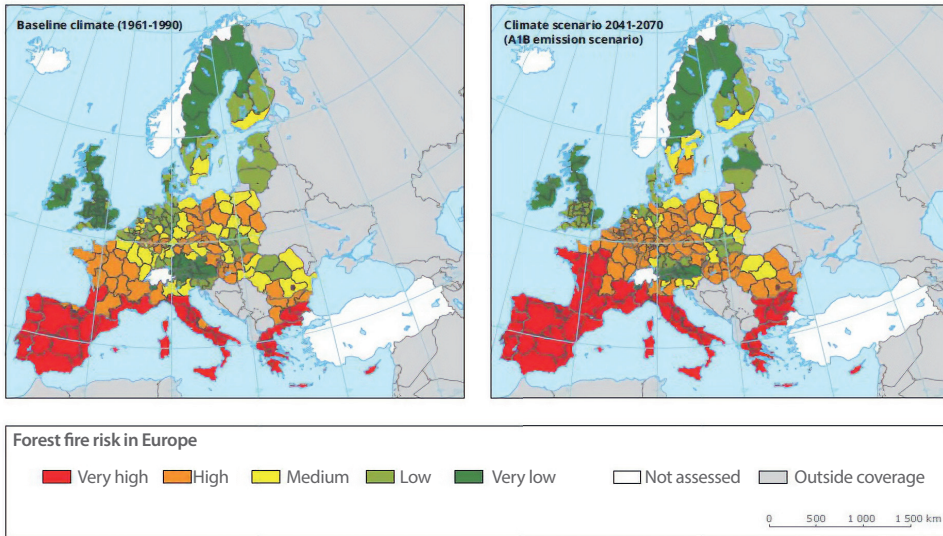


Figure 9: Change in fire risk trend between 1981–2000 and change compared to the period 2041–2070

Source: European Environmental Agency.

Some domestic research predicts that in the future the distribution of precipitation in the Carpathian Basin will become more uneven and the average daily temperatures in summer and autumn will also increase. The effects of climate change will also be seen in the extension of high fire risk periods, the increase in the number and distribution of wildfires, and the increase in fire intensity. However, forest fire prevention can only be effective if potential risks are identified and potential impacts can be evaluated.

## Wildfire indicators and the definition of high fire risk periods on the country level

The wildfire risk of a country or a region is characterised by the number and burnt areas in national reports. Many conclusions can be drawn from these data, especially if they include additional information on the fuel conditions of the burnt areas. However, in our opinion, they are poorly suited to measuring the effectiveness of fire prevention activities and comparing annual data sets. It does not matter if there were 100 wildfires in 1 million hectares of endangered forest that resulted in 1,000 hectares of burned areas or if it evolved from 100,000 hectares of endangered forest. It should also be examined whether there were 50 high fire risk days or 150 in a year, as the same burnt area is a great achievement if the length of the endangered period increases. Few wildfires do not necessarily mean that there is no wildfire risk, but they can also mean that the forest fire prevention system works well. In this case, we can say that fire prevention is more effective from both an

economic and ecological point of view. Due to several factors influencing wildfires, we need to produce an intensity ratio, where the numerator contains the data of the fires that occurred in the given period and the denominator contains the number characterising the potential fire risk of the period. The change in the intensity ratio shows more effectively the effect of the measures in the case of weather-dependent forest fires. As the size of the endangered forest area did not change during the examined period in Hungary, the number and extent of annual fires should be compared with the degree of fire risk or the length of the periods. Of course, an intensity ratio can be developed that takes into account territorial changes or even the extent of individual measures.

To be able to compare the number and burnt area in forest fires each year, it is necessary to define the concept of a wildfire risk day and region. The spring and summer fire seasons will be considered separately for different fuel conditions and fire causes.

Two questions need to be always answered:

1. When do we consider a particular day to be a high fire risk day?
2. What is the size of the area to which the concept of a fire day is applied?

For the first question, we can start with the number of fires that have occurred or meteorological and fire risk data, which show the possibility of a fire being potentially caused. For the second question, the fulfilment of the wildfire risk day criterion should be applied to the area related to the data. This method can sometimes lead to simplification.

Looking for possible solutions, we have found the following four criteria feasible for Hungarian wildfires.

- at least 2 wildfires per 1 hectare
- 5-day moving average and trend of the number of fires
- the number of summer and heat days compared to the number of wildfires
- criteria system based on fire weather index

## **At least 2 wildfires per 1 hectare**

When evaluating the data of the fires, we considered a wildfire risk day when at least 2 wildfires occurred in one day with a total burned area of at least one hectare. Fires in spring usually start in the grass fuel and in many cases, they spread from there to the forest. So it is worth considering the two types of fire (wildfire and forest fire) together in this criterion. Due to the higher number of cases of spring wildfires and their territorial focus in the Northern Hungary region, this criterion can be applied nationwide for the spring fire season. The limitation of its use happens when the number of fires is reduced or if fire prevention is significantly improved. In this case, if no fire occurs on a potentially high fire risk day, the criterion does not indicate this. In the last decade, there have been an average of 77 days throughout the year when no wildfire occurred.

Table 3: Days when no wildfire occurred between 2011–2021

Year	Number of days	Spring	Summer	March–April
2011	48	4	6	1
2012	61	12	4	0
2013	87	35	8	16
2014	95	19	11	0
2015	76	15	5	0
2016	89	19	7	4
2017	71	14	8	2
2018	91	26	6	9
2019	70	14	5	0
2020	86	2	9	2
2021	80	20	1	0

Source: Compiled by the authors based on the data of the National Food Chain Safety Office and the Forest Fire Information System.

The two highly endangered months (March and April) had a total of 34 days in the last decade when no wildfire burned. There were a total of 109 days when 100 or more wildfires occurred in one day. 47% of these fires were in 2011 and 2012. The most fires occurred on the 17<sup>th</sup> of March 2012, when a total of 462 wildfires were recorded.

Figure 10 shows the number of days when at least two wildfires occurred on the same day during the spring fire season and the average burned area exceeded one hectare. In the examined period, the spring fire season was affected by the distribution of precipitation. The number of days meeting the criterion increased in the drought springs. Rainy years have resulted in a decline, but the last two years of the decade have shown a slight increase based on the moving average.

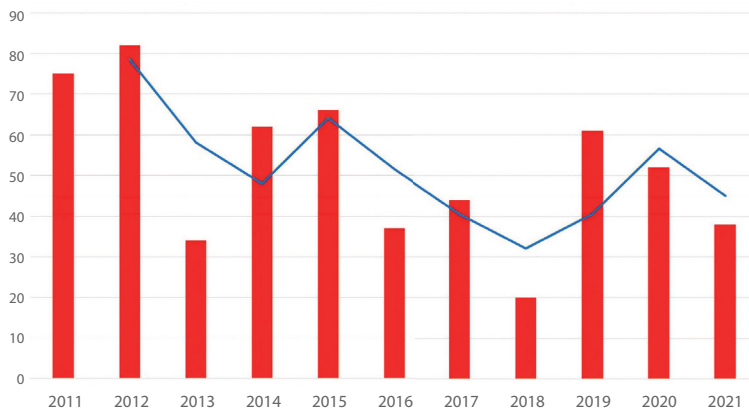


Figure 10: Number of days when at least 2 wildfires occurred during the spring fire season and the average burned area exceeded 1 ha (2011–2021)

Source: Compiled by the authors based on the data of the National Food Chain Safety Office and the Forest Fire Information System.

Figure 11 shows the number of days when at least two wildfires occurred on the same day during the summer fire season and the average burned area exceeded 1 hectare. It shows a declining trend in the period between 2011–2021 in terms of the moving average.

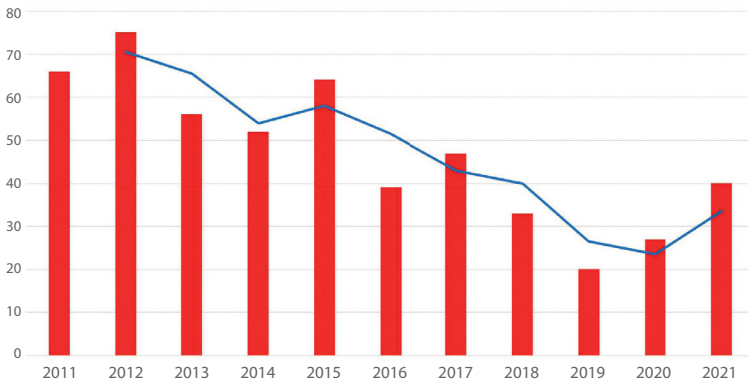


Figure 11: Number of days when at least 2 wildfires occurred during the summer fire season and the average burned area exceeds 1 ha (2011–2021)

Source: Compiled by the authors based on the data of the National Food Chain Safety Office and the Forest Fire Information System.

Figure 12 shows that large fires of more than 50 hectares occurred during well-defined periods of the year. The high risk of the spring period is also confirmed by the data displayed on the graph.

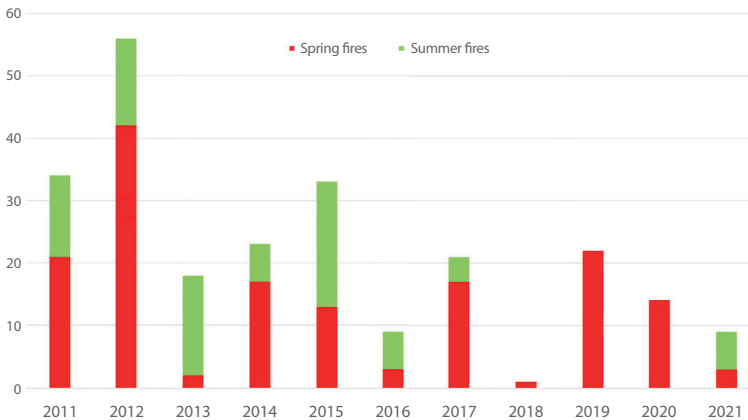


Figure 12: Number of days with more than 50 hectares burned areas (2011–2021)

Source: Compiled by the authors based on the data of the National Food Chain Safety Office and the Forest Fire Information System.

## 5-day moving average and trend of the number of fires

The trend of daily fire numbers can also be determined by the moving average method. Each year represents a separate fire season, so every year can be examined separately. So the effect of fluctuations within a year can be filtered out. This method helps to predict the processes expected in the coming days, i.e. the increase or decrease in the number of fires. The moving average method is a little bit more inaccurate, but it can be used and accepted in all cases. In the case of wildfires, we examine the 5-day moving averages, as the fine fuel responds to the amount of precipitation from the previous 5 days (100 hours).<sup>28</sup> The moisture content of the fuel parts is determined by the environmental conditions and their size, shape and relative surface. The moisture content index shows how quickly the fuel part can reach the equilibrium state with the relative humidity. According to it, we distinguish biomass parts that reach equilibrium in 1–10–100–1000 hours. In the future, meteorological data and the values of the fire weather index derived from them will be needed to study the processes behind the decrease and increase in the number of fires. Figure 9 shows the number of daily fires in the period from the 15<sup>th</sup> of February to the 30<sup>th</sup> of April 2020 and the 5-day moving average calculated from them. The fluctuations are adjusted by the moving average, but the trend expected from the values of the last 5 days is well shown during the vulnerable period of the spring fire season.

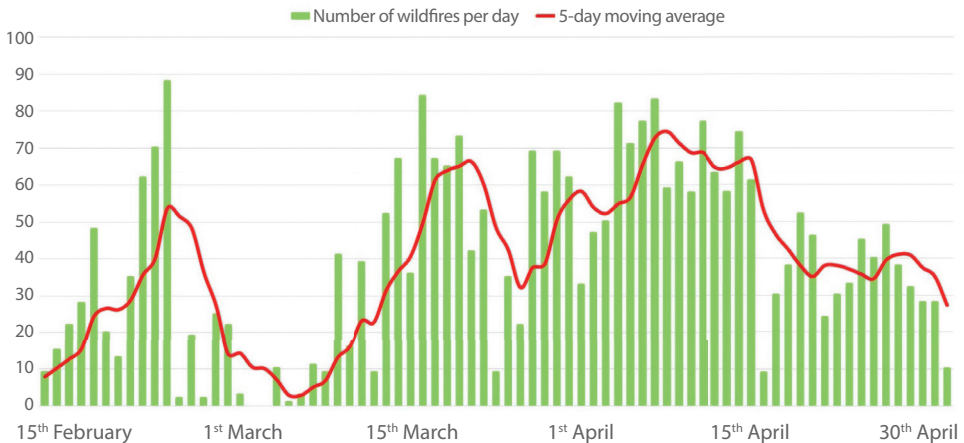


Figure 13: The number of daily wildfires in the period from the 15<sup>th</sup> of February to the 30<sup>th</sup> of April 2020 and the 5-day moving average calculated from them

Source: Compiled by the authors based on the data of the National Food Chain Safety Office and the Forest Fire Information System.

<sup>28</sup> Mike Wotton: *A Grass Moisture Model for the Canadian Forest Fire Danger Rating System*. 8<sup>th</sup> Fire and Forest Meteorology Symposium, 2009.

## Number of summer days, heat days and number of forest fires

During the summer fire season, light dead fuel with a large specific surface area can be burned within a few hours even after a small rainfall, if the weather is warm. It can be said that wildfires can typically develop in summer and on heat days. As the data refer to Hungary, we can find areas where the conditions for generating a fire do not exist. In general, however, the number of summer and heat days is a good indicator of the length and level of risk of the summer fire season.<sup>29</sup>

During the summer fire season, 38.1% of fires and 27.6% of the burned area are generated. In Figure 14, we compared the number of wildfires in the period between 2011–2021 to the number of summer and heat days. We considered those wildfires that resulted in at least 0.5 hectares of burnt area. Smaller fires usually occur due to the careless use of fire and not because of meteorological conditions. Over the last decade, the number of wildfires has shown a declining trend compared to the summer and heat days. To refine the system of fire ban criteria during the summer fire season, it is recommended to take this trend also into account in the future.

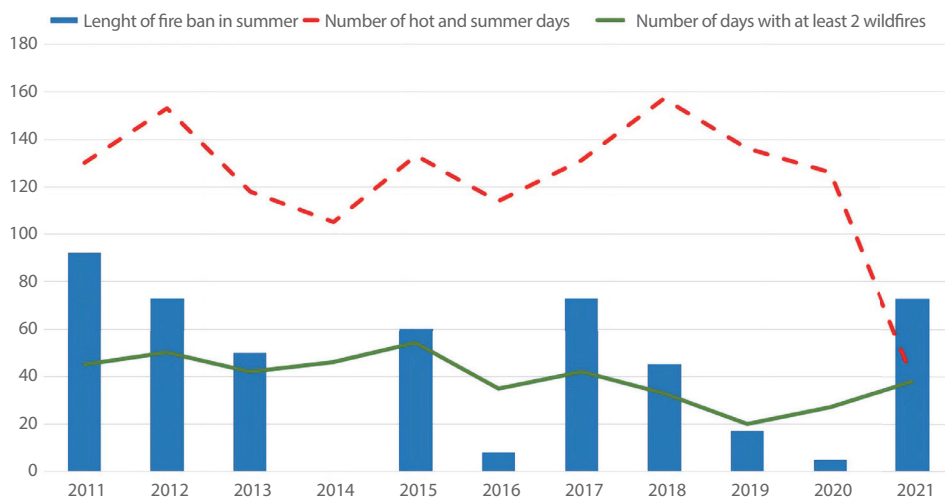


Figure 14: Comparison of summer and heat days with the number of wildfires reaching at least 0.5 hectares

Source: Compiled by the authors based on the data of the National Food Chain Safety Office and the Forest Fire Information System.

<sup>29</sup> Péter Debreceni – Péter Pántya: A fokozottan tűzveszélyes időszakok meghatározásának lehetőségei [Possibilities for Definition of High Fire Danger Periods]. *Műszaki Katonai Közlöny*, 29, no. 1 (2019). 243–260.

## Criteria system based on fire weather index

The Canadian Fire Weather Index is also used by the European Union's Joint Research Centre to assess the risk of wildfires in the coming period. The Canadian system models the changes in fuel moisture content based on the meteorological parameters in an area, where the weather data is available. If we would like to use the index at the operational level, its values must be validated at the member states' level.<sup>30</sup>

Before presenting the effects that can be detected based on the criteria system based on the FWI, we present the structure of the index. The index contains six subcomponents, the first three shows the moisture content of the fuel in the soil based on meteorological parameters. The two other subcomponents of the model show the expected fire behaviour and provide us with some information about the propagation of the fire. The sixth element is the value of the composite index, which is derived from the sub-indices. The sub-indices are calculated from the combination of different meteorological factors.<sup>31</sup>

Humidity indices are calculated first. A value indicating the moisture content of fine fuel with a diameter of less than 1 cm expresses the flammability. The forest litter moisture value characterises the moisture content of the loose, less compact soil layer for the average depth. The drought value refers to the moisture content of larger dead biomass elements. It can be used to predict drought periods and ignition. Because wildfires are most easily generated and propagated in the fine fuel, therefore, the values of the fine fuel component are important in determining the fire risk period in the spring. This sub-index responds to the amount of precipitation over the previous five days, so in the rapidly changing spring period, as this value increases, the probability of fires also increases exponentially.

In the second step, two sub-indices of the extent of the fire are calculated. The value indicating the expected rate of fire spread is the value calculated from the wind speed and the moisture content of the fine fuel. The fire development value is a combination of the forest litter and the drought value, which shows the probability that the fire can spread most easily to the biomass types with higher burning intensity.

In the third step, the complex value for forest fire hazard is calculated, which is a combination of the previous two values. FWI values are classified into six classes, which are displayed on a map. The same classification is applied to all countries in Europe, so they are comparable with each other. However, a country-specific scale may need to be developed in the future due to the effectiveness of official measures.

The index can be used to show the effects of the weather on the expected development of fires. The index can be used to assess the effects of weather on the moisture content of biomass in the forest, in case of large fires, it helps to estimate the expected fire behaviour. Changes in the sub-indices of biomass provide an opportunity to continue monitoring the fire potential.<sup>32</sup> The index also refers to the fire intensity per unit of the fire front;

<sup>30</sup> Joaquín Bedia et al.: Seasonal Predictions of Fire Weather Index: Paving the Way for their Operational Applicability in Mediterranean Europe. *Climate Services*, 9 (2018). 101–110.

<sup>31</sup> Christian van Wagner: *Structure of the Canadian Forest Fire Weather Index*. Ottawa, Department of the Environment, Canadian Forestry, 1974.

<sup>32</sup> B. D. Lawson – O. B. Armitage: *Weather Guide for the Canadian Forest Fire Danger Rating System*. Edmonton, Natural Resources Canada, Canadian Forest Service, Northern Forestry Centre, 2008.

therefore, in case of large fires, it can also be used to determine the conditions required for the firefighting. The index can also be used to delimit the periods and the locations of the country, where the conditions of controlled ignitions have been established. As a result of the index, the beginning of the fire season can be determined, but also a forecast of the expected fire season can be made. The map and the updates on the daily fire danger are available on the EFFIS website.<sup>33</sup> During vulnerable periods, the index is recalculated daily, thus providing a three- and six-day fire danger forecast. The meteorological data required for FWI are provided by the German and French meteorological services (Meteo-France and DWD). To calculate the FWI, a biomass map is generated based on the Corine Land Cover (CLC) and Map of Natural Vegetation of Europe (MNVE) databases. FWI values are classified into fire danger classes, which are displayed on a map.

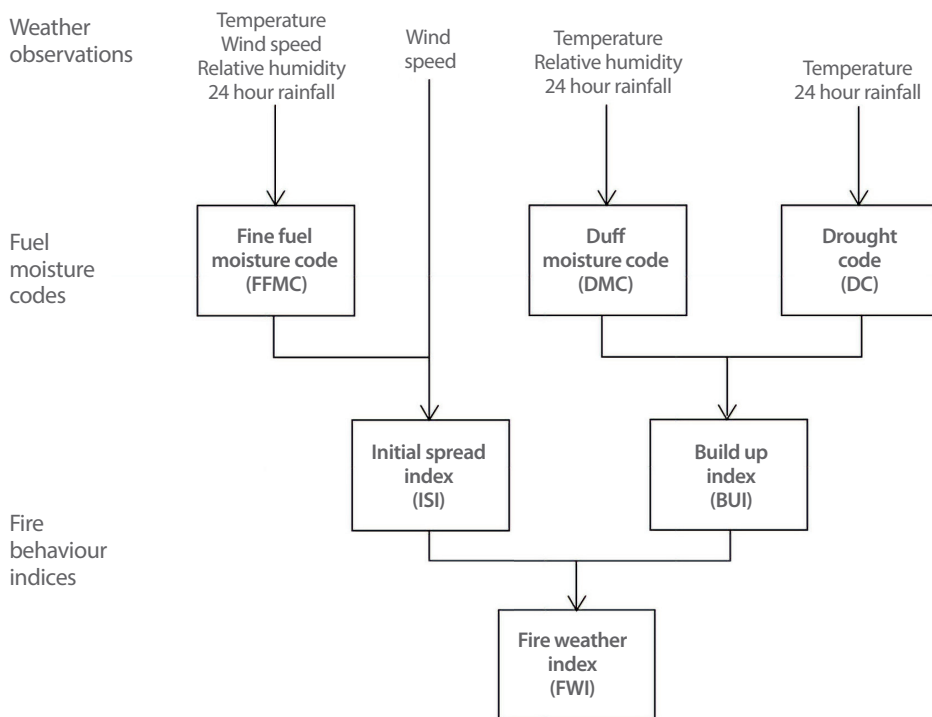


Figure 15: Structure of the Canadian Fire Weather Index

Source: Canadian Forest Fire Weather Index (FWI) System

<sup>33</sup> European Forest Fire Information System ([http://effis.jrc.ec.europa.eu/static/effis\\_current\\_situation/public/index.html](http://effis.jrc.ec.europa.eu/static/effis_current_situation/public/index.html)).



## Relationship between fire risk days and fires based on the weather index

The Joint Research Centre provides FWI values on a 28 km resolution raster map daily. The relationship between FWI and wildfires was examined over two years for the entire territory of the country. According to the JRC recommendation, a day in the spring fire season was considered risky if the FFMC value was greater than 75; and in the summer fire season when the FWI value was greater than 19.

By using GIS, we examined two aspects in 2012 and 2018.

1. Daily, how many pixels meet the criteria for the wildfire risk day separately in the spring and summer fire seasons.
2. What are the grid points where the most wildfires occur in spring and summer?

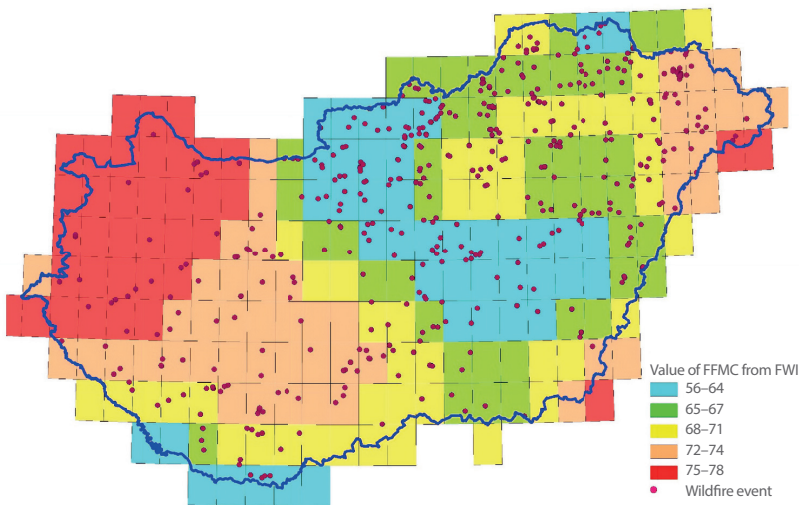


Figure 16: Grid of Fire Weather Index with values of FFMC and wildfire events on the 17<sup>th</sup> of March 2012

Source: European Forest Fire Information.

Figure 16 shows that during the spring fire season, most fires occur in that part of the country where, based on the fire weather index Fine Fuel Moisture Code sub-index, the wildfire risk is not yet high. This contradiction shows that human factors (cause of fire) must also be taken into account in the fire risk assessment. In the geospatial analysis, we examine the values of the Fire Weather Index grid shown in Figure 16. The data of the grid were downloaded from the freely available database of the Copernicus Emergency Management Service. The European Space Agency created a harmonised database in the framework of the Copernicus program, which contains the values of the index. After registration, the data can be freely used for research purposes. The database works by drawing a 0.25-degree grid over the entire globe. Index values were given for each grid

point and each day. The index contains 8 sub-indexes. This means that for each day there is a grid point identifier and 8 index values for a date.<sup>34</sup>

Figure 17 shows how many pixels were classified as high fire risk daily between February and May in 2012 and how many of these grid points resulted in wildfires. The graph shows that in the early spring period when it was a dry period, the moisture content of the dead biomass reacted quickly to the rainless period. At the end of spring, due to rainier days, the number of the grid points decreased.

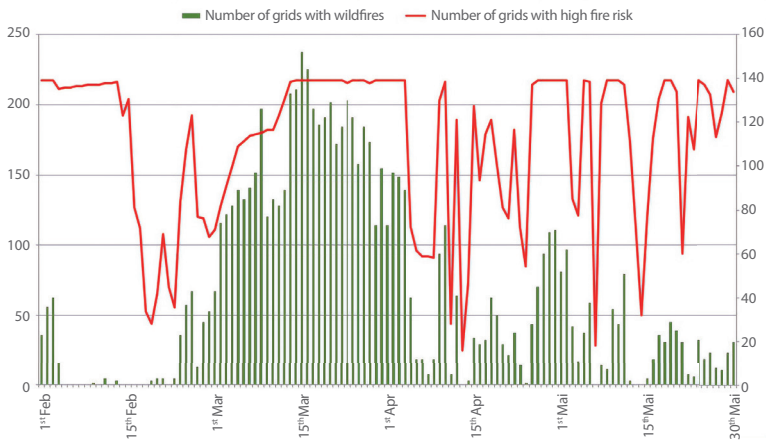


Figure 17: The number of grid points that are considered wildfire risk days and the number of grid points affected by wildfire in spring 2012

Source: Compiled by the authors based on the data of the National Food Chain Safety Office and the Forest Fire Information System.

In the summer of 2012, due to a more even distribution of precipitation, there were several shorter periods when a fire risk developed in most parts of the country, as shown in Figure 18. As the fire danger area increased, the number of grid points affected by the fire also increased slightly.

<sup>34</sup> Fire Weather Index ERA5 dataset (<https://confluence.ecmwf.int/display/CKB/ERA5>).

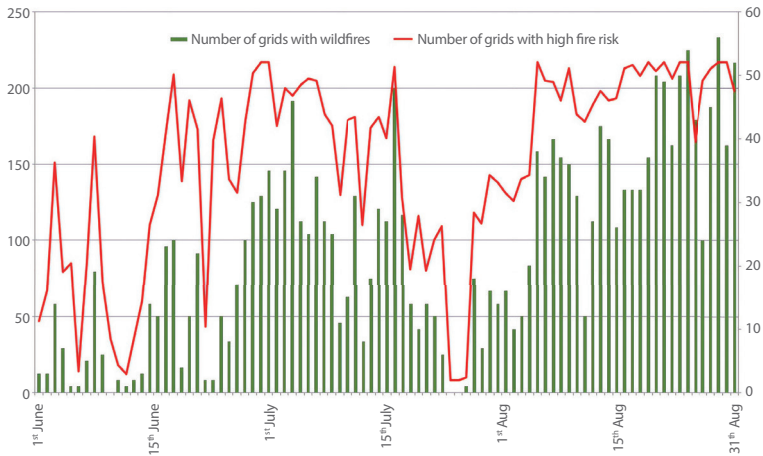


Figure 18: The number of grid points that are considered wildfire risk days and the number of grid points affected by wildfire in summer 2012

Source: Compiled by the authors based on the data of the National Food Chain Safety Office and the Forest Fire Information System.

In the spring of 2018, due to the rainy weather, no long-term fire hazard period developed in Hungary. In the second half of spring (April), there was a four-week period, where high-danger grid points were registered in nearly two-thirds of the country. Compared to the situation in 2012, the number of grid points where ignition took place despite the risk of fire has significantly decreased (Figure 19).

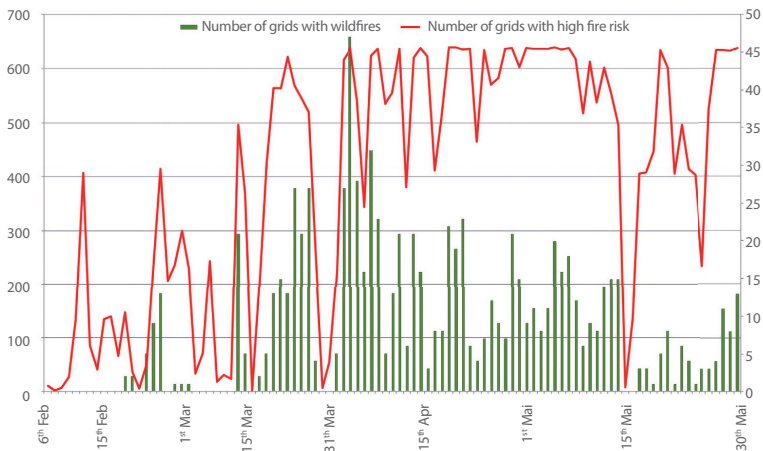


Figure 19: The number of grid points that are considered wildfire risk days and the number of grid points affected by wildfire in spring 2018

Source: Compiled by the authors based on the data of the National Food Chain Safety Office and the Forest Fire Information System.

During the summer fire season, there were days in August when the fire risk period was present in half of the country (Figure 20).

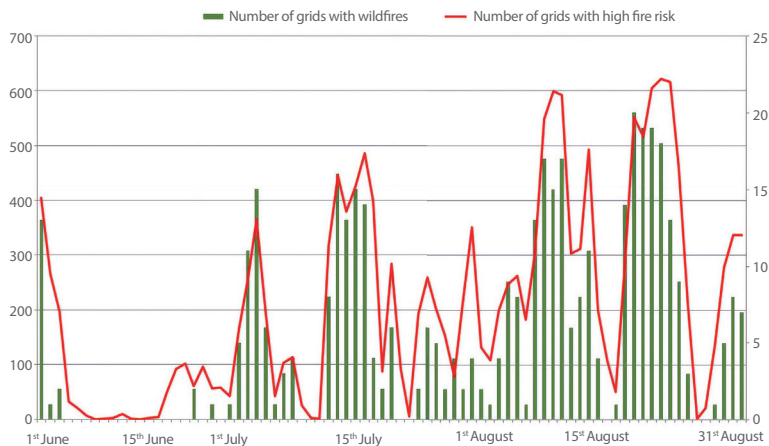


Figure 20: The number of grid points that are considered wildfire risk days and the number of grid points affected by wildfire in summer 2018

Source: Compiled by the authors based on the data of the National Food Chain Safety Office and the Forest Fire Information System.

## Summary

The fire risk depends on the combined effect of several factors: climatic conditions, vertical and horizontal structure of the vegetation, moisture content of the dead biomass, forest management methods, forest fire prevention activities and socio-economic conditions. In case of droughts, because of the weather conditions lots of wildfires occur. Indicators within a year help us to assess the fire risk. Forecasting the risky periods during the fire season is very important for the preparation and implementation of official measures. Indicators based on the number of fires can be used as indicators to evaluate and compare each year. One of the purposes of the paper was to define indicators that can be used to compare the number and extent of wildfires each year with the degree of the daily fire risk and the length of periods during which the vegetation fires occurred. For this, we defined the concept of the high fire risk days and the endangered areas and parts of the country in the Hungarian climatic conditions. We also examined the spring and summer fire seasons separately, because of the different fuel conditions and the causes of fire ignition. In addition, we examined statistical data on wildfires and applied GIS systems. We have found a correlation between the daily fire risk values, the number of wildfires and the burned area.

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# Examination of the Application of Currently Used, New or Additional Firefighting Personal Protective Equipment<sup>1</sup>

Lilla HORVÁTH<sup>2</sup>

*The publication focuses on the safety of the damaged environment that arises during firefighting interventions, the protection and ergonomic factors of personal protective equipment currently used in Hungary and internationally, and on increasing and improving the level of protection and other issues related to firefighting interventions. Personal protective equipment must provide the highest level of protection against unforeseen threats in different directions, taking into account proportionality. The basic idea of the publication is to analyse and evaluate the typical sources of danger in the firefighters' work environment in the domestic and international environment, to examine the personal protective equipment in use from several aspects, and to examine the applicability of the currently used personal protective equipment for firefighters. The publication covers the load-bearing capacity of the human body, taking into account age, the concept and interpretation of ergonomics, and the implementation of personal protective equipment in practice. In addition, the author mentions the firefighting accidents of the last 10 years in Hungary and the role of personal protective equipment in them. There is also talk of processing firefighting accidents abroad. Examining the practice of the National Directorate General for Disaster Management settings, maintenance and training will also be one of the topics of the publication.*

**Keywords:** firefighter, personal protective equipment, ergonomics, accident, the human body

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## Introduction

People have seen fire as a danger since prehistoric times. The increase in the number of devices used, the population and the number of residential buildings located close to each other led to more and more fire incidents, so it was necessary to organise a squad, a team, which can effectively and quickly put out fires in an urbanised environment.

Firefighting personal protective equipment has undergone many improvements over the past decades, as the number and size of environmental hazards have changed thanks to technological progress. An excellent example within this topic is the appearance of cars at the end of the 1800s; before this period we could not talk about their breakdown or road accidents caused by them as a source of danger.<sup>3</sup> Nowadays, not a day goes by without a car accident that requires the help of firefighters, whether we are talking about technical rescue or firefighting. And this was just one example of all the sources of danger that have become part of our lives in recent decades. The spread of electronic devices (television, computer, laptop, etc.) in addition to its positive, quality-of-life-improving effects also includes dangers that not all users are aware of. Improper use of an electric heater can easily cause a fire in anyone's home, and negligence can even cost human lives.

In addition to technological development, buildings have also changed, since with the appearance of multi-story buildings, not only the personal protective equipment of firefighters but also vehicles and specialised equipment have adapted to more complex interventions.

In addition, the concept of labour protection appeared and gained more and more space, which was meant to protect the lives of workers. By creating a legal environment and with theoretical and practical training that adapts to the constantly changing world, we can reduce the damage caused during interventions and at the same time protect the physical integrity and health of the firefighters who intervene.

## Environmental hazards

Responding firefighters can be at risk from many sources during their work. The first thing that comes to everyone's mind is the heat load since it is one of the most significant sources of danger during firefighting. In such cases, several factors play a role, since, in addition to the high temperature, the time factor is also an important aspect, i.e. it is significant how long the intervening firefighter can withstand the given heat load. The firefighter's personal protective equipment and, of course, the firefighter's health also plays a big role in this.

An accident can also occur during the fire investigation after extinguishing the fire, which mostly results from tripping or slipping since the floor is by no means safe after a fire due to all the materials that have tipped over and fallen on it. In addition, the structure of the building can also weaken, i.e. it can fall on the person who is under it at a careless moment.

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<sup>3</sup> History: Who Built the First Automobile? *History*, 11 December 2012.



In addition to the heat load, the intervening firefighters can face a mechanical hazard, and the personal protective equipment plays a prominent role in preventing or reducing the injury. For example, a case can be mentioned when the building is entered through the window. In such cases, after breaking the window glass, a splinter may remain in the window frame upon entering the room, which may cut the firefighter's skin. The firefighter's protective jacket, protective gloves and protective boots are of course primarily developed for protection against heat and flame, but in addition, due to the quality and thickness of the material, they may be able to provide an adequate level of protection against cuts and punctures.

Road defects, uneven surfaces and liquids spilling onto the road represent an additional source of danger. During a firefighting intervention, be it extinguishing a fire in a building, factory, forest, or other technical intervention, the intervening firefighters work in an unfamiliar place, they do not know the dangers of the given place, so there is a greater chance of tripping and falling. In winter, when the outside temperature drops below freezing, accidents due to slipping on ice can often occur. The number of road accidents increases not only for firefighters, but also for civilians participating in traffic, so the probability of an accident involving firefighters also increases proportionally.

The breathing system of the intervening firefighters is also exposed to danger at the scene of damage. In the case of an established forest fire, the abiotic, biotic and management factors determine the formation of the fire itself, its spread, and the size of the affected area.<sup>4</sup> During combustion, many different chemicals are released into the air, such as carbon monoxide, nitrogen oxides, sulfur dioxide, or hydrogen chloride.<sup>5</sup> These hurt the human body, especially if the person inhales them frequently and/or over a long period. In addition to forest fires, it is also necessary to mention the smoke caused by fires in buildings and various equipment (e.g. electronic equipment), since in such cases substances with a strong toxic effect on the body can enter the air. In such cases, the protection of the intervening firefighters is provided by the compressed air breathing apparatus.

In addition to the sources of danger from the environment, I think it is important to mention the sources of psychological danger, since the firefighters who intervene are regularly faced with situations and sights that use up the nervous system to a great extent. First of all, the stress caused by the possible alarm, which keeps the body on constant alert, should be mentioned. In addition, the responsible and dangerous physical work certainly tests their psychological state, since every intervention is different, and they still have to make quick and effective decisions for the sake of themselves, their companions, and the lives of the persons to be rescued. Finally, I would also like to mention the sight of dead

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<sup>4</sup> László Bodnár: *Az erdőtüzek oltásának hatékonyságát növelő módszerek kutatása és fejlesztése* [Research and development of methods that increase the efficiency of extinguishing forest fires]. PhD thesis. Budapest, University of Public Service, Doctoral School of Military Engineering, December 2021. 22.

<sup>5</sup> George Broyles: *Wildland Firefighter Smoke Exposure*. United States Department of Agriculture, October 2013. 4.

people – especially children – which requires a strong psychological background so that it does not cause posttraumatic stress<sup>6</sup> and/or other physical illnesses later on.<sup>7</sup>

Finally, it is worth mentioning the mandatory sports activities and the exercises that deepen professional knowledge. As before any sports activity, it is strongly recommended to warm up with adequate quality and time before exercising among firefighters, so that injuries (e.g. torn ligaments)<sup>8</sup> do not occur in the absence of this. Accidents of this nature are usually caused by human error or inadequate prior training.

## Brief presentation of the personal protective equipment for firefighters

In the following section, I would like to describe the personal protective clothing used by the firefighters in Hungary, spiced up with a brief historical introduction. In addition, in the course of the international outlook, the personal protective equipment of firefighters in the United States will also be briefly presented. The presentation can only be of interest to the reader, the aim is no comparison.



Figure 1: Firefighters' protective clothing

Source: Drawn by Anna Veronika Grósz.

<sup>6</sup> "PTSD (posttraumatic stress disorder) is a mental health problem that some people develop after experiencing or witnessing a life-threatening event, like combat, a natural disaster, a car accident, or sexual assault" (for more information see National Center for PTSD: *Understanding PTSD and PTSD Treatment*. May 2019. 3).

<sup>7</sup> Ágoston Restás: *Pszichológia a tűz frontvonalában* [Psychology on the Frontline of Fire]. *Védelem Tudomány*, 1, no. 3 (2016). 55.

<sup>8</sup> O. P. Aneja: Warming-up, Cooling Down – Meaning and Significance. *European Journal of Molecular and Clinical Medicine*, 7, no. 8 (2020). 5263.

The personal protective equipment, or more precisely clothing, worn by the firefighters can be grouped according to the areas to be protected (Figure 1).

### ***Firefighters' protective helmet***

The standardised firefighters' protective helmets must fit the wearer's head properly. With the help of the straps, or buttons on the helmet, the user will not have any problems adjusting it, even when wearing protective gloves. After proper adjustment to the given head size and shape, long-term wearing does not cause discomfort or pain for the firefighter. Thanks to its material properties, it also withstands high temperatures, thus protecting the firefighter's head. In addition, of course, it also ensures that an object falling on the head from a height does not cause a head injury to its user.

### ***Firefighters' protective hood***

Firefighters' protection against extreme weather or increased heat radiation can be increased with the firefighters' protective hood. Thanks to the appropriate material properties (drainage, double-layer), it ensures increased protection of the intervening firefighters.

### ***Firefighters' protective clothing***

The firefighters' protective clothing consists of pants and a jacket, which overlap each other at the waist for greater protection. Thanks to their material composition, they provide the necessary waterproofness, as well as adequate heat, flame and mechanical protection for their users.

### ***Fire protection gloves***

Firefighters' protective gloves provide a high level of protection to the firefighter who wears them. Thanks to the special material properties, it has excellent heat (contact and radiant) protection, and the reflective strap that may be placed on the wrist increases visibility (e.g. Seiz – Fire-Fighter Premium).<sup>9</sup>

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<sup>9</sup> Seiz: Fire-Fighter Premium.

## ***Firefighters' safety boots***

All of the regularised firefighters' protective boots have all the protection necessary to preserve the integrity of the intervening firefighters. First of all, it is worth mentioning the protection against thermal radiation, as well as the resistance to chemical and mechanical effects (e.g. piercing, cutting). In addition, it reduces the wearer's risk of a major injury (e.g. broken ankle) during a trip on uneven terrain.

## ***Protective gloves against mechanical effects***

Regarding protective gloves, the MSZ EN<sup>10</sup> 388:2016 standard defines several requirements for mechanical hazards, which are as follows: wear, tear, puncture, impact and blade cutting. Based on the standard, the protection levels vary between 1 and 5, where 1 is the lowest and 5 is the highest level of protection. In 2016, the standard was supplemented with regard to protection levels, and resistance to straight blade cutting and impact resistance (A-F level) became an additional aspect. Intervening firefighters belonging to the National Directorate General for Disaster Management (hereinafter: NDG DM) – and those in other positions who wear protective gloves against mechanical effects – may only wear gloves, i.e. gloves that meet the protection level of all regulations at least level 2.<sup>11</sup> These gloves are typically used by the intervening firefighters during technical rescues, i.e. only in the event that heat stress cannot (any longer) be expected at the scene of damage.

## ***Personal protective equipment for preventing falls from a height or the impact of a fall<sup>12</sup>***

The firefighters' climbing belt, also known as the work position adjusting belt, provides the intervening firefighter with protection against falling when working at height. Periodic safety reviews and visual inspections before work must be carried out at intervals specified by the manufacturer, as the material may be damaged or aged.

## ***Noise protection earplugs***

The noise protection earplugs are part of the accessories on the car engines, which come into play when the firemen are in a hurry e.g. storm damage and the gasoline engine chainsaw are needed, which hurts the ears and damages the hearing if used for a long time.

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<sup>10</sup> Mark of the issuer of Hungarian national standards.

<sup>11</sup> Regulation 34/2021 on the provision of personal protective equipment to the personnel of the NDG DM, Appendix.

<sup>12</sup> Regulation 16/2018 on the periodic inspection and review of firefighting ladders, personal protective equipment, equipment and firefighting ropes for preventing falls from a height or the impact of a fall of the NDG DM.

## ***Breathing mask and compressed air bottle***

The units of the compressed air breathing protection device are as follows:

- compressed air bottle
- carry structure
- lung machine
- mask
- pressure reducer
- safety units (signal, acoustic warning, pressure control)
- additional units<sup>13</sup>

The compressed air breathing cylinders used today are no longer made of steel, but of composite, which means that their mass is also much smaller, making it easier to move with them, which is advantageous from an ergonomic point of view. The composite bottles used by the Disaster Management operate at a pressure of 300 bar, and their internal volume is between 6 and 6.8 litres.<sup>14</sup>

## **Brief historical overview of personal protective equipment in domestic and international contexts**

In Hungary, in 1834, the Council of Governors distributed to the cities and counties new firefighting personal protective equipment and equipment that provided a higher level of protection for the people involved in firefighting (Figure 2). In addition, many suggestions were made, such as dipping clothing in potash for flame retardant purposes.<sup>15</sup>

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<sup>13</sup> László Czíkora et al.: *Műszaki ismeretek I. A tűzoltó szakképzésben résztvevők számára*. Budapest, BM Katasztrófavédelmi Oktatási Központ, 2003. 119.

<sup>14</sup> Czíkora et al. (2003): op. cit. 120.

<sup>15</sup> János Szilágyi – Károly Szabó: *A tűzrendészet fejlődése az őskortól a modern időkig*. Budapest, BM Könyvkiadó, 1986. 136.

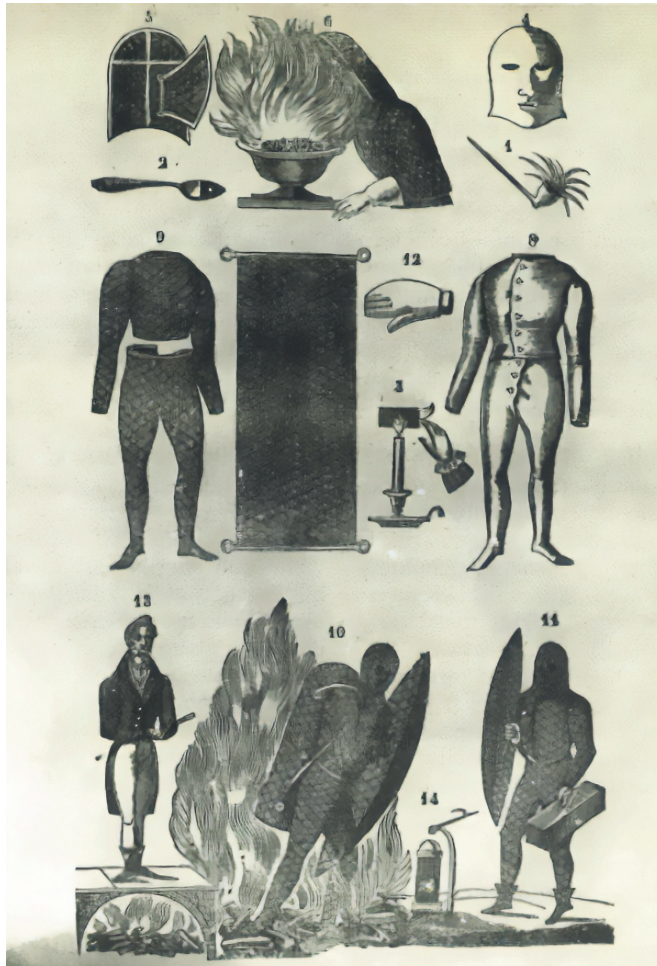


Figure 2: Recommended personal protective equipment from the past

Source: Szilágyi-Szabó (1986): *op. cit.* 137.

Later on, this protective equipment was continuously developed to be more resistant to the harmful effects caused by fire. At the same time, of course, changes also took place in the field of professional equipment, thus ensuring more effective intervention and protection. Even if ergonomics was not defined as a concept, comfort and wearability played an increasingly important role. By continuously improving the weight and design of the protective clothing, the firefighter can participate in firefighting for a longer period and can also get closer to the fire.

In Hungary, at the Mosonmagyaróvár Professional Fire Command, the Firefighters exhibition can be viewed at the Command, which provides an introduction to the past and present of firefighters' personal protective equipment and specialised equipment (Figure 3).



Figure 3: Presentation of firefighting climbing belts

Source: *Katasztrófavédelem* (2020): *op. cit.*

Nowadays, the staff of Disaster Management already uses modern personal protective equipment. The deployment of protective clothing complies with the MSZ EN 469 standard, thereby ensuring the appropriate level of protection. An excellent example is the R13 deployment protective clothing, which has several layers that resist the effects of heat and flame, has water-repellent properties, and is also able to withstand a certain level of mechanical and chemical influences.

In an international context, it is worth mentioning the firefighting protective equipment of the United States of America, namely the history of the firefighters' protective helmet. It was a man named Jacobus Turck who developed the protective helmet in the early 1700s, the raw material of which was nothing but leather. In later years, in 1836 to be exact, Henry T. Gratacap designed the helmet, similar to what we can still see on the heads of firefighters in the United States.<sup>16</sup>

In addition, of course, other protective clothing has also undergone development. The raw material used to be mainly wool and cotton, and thanks to the rapid increase in rubber production, they were increasingly replaced by rubber as a raw material. From the middle of the 1900s, fire resistance, and thus the quality of the material, played an increasingly important role. The regulations were included in standards, which was able to unify the regulations.<sup>17</sup>

<sup>16</sup> Salty Dog: Wearing Their Fire Helmets Backwards. *Gettin Salty Apparel*, 09 January 2015.

<sup>17</sup> Paul Hasenmeier: The History of Firefighter Personal Protective Equipment. *Fire Engineering*, 16 June 2008.



In the United States of America, the personal protective clothing used by responding firefighters is also called Bunker Gear or “Turnout Gear”.<sup>18</sup> The pants and jacket are made of special materials, multi-layered to provide adequate protection against flames and heat. In the U.S., unlike clothing in Hungary, the colour of the protective clothing is mainly yellowish-brown, but yellow and black are also present. Reflective strips in several places on the clothing ensure visibility.

Firefighters in the United States typically retain the original form of the firefighters’ protective helmet. The traditional protective helmet is considered more special due to its design, but there have been several feedbacks from the firefighters who use it, that they cannot look up in full deployment protective clothing, with a compressed air bottle on their back, because the flange of the helmet gets caught in the top of the compressed air bottle<sup>19</sup> (Figure 4). This kind of problem does not arise with European protective helmets.



Figure 4: Hooking a firefighters’ protective helmet into the compressed air bottle

Source: Park Huiju et al. (2014): *op. cit.* Figure 5.

## The load-bearing capacity of the human body

The human body is structured hierarchically, the smallest unit of which is the cell, which also has an independent life phenomenon. Cells with the same function and similar shapes are assembled into tissue. The next level is the organ, which is made up of tissues, and then

<sup>18</sup> Lynn M. Boorady: Bunker Gear for Fire Fighters: Does It Fit Today’s Fire Fighters? *Journal of Textile and Apparel, Technology and Management*, 9, no. 3 (2015). 2.

<sup>19</sup> Park Huiju et al.: Assessment of Firefighters’ Needs for Personal Protective Equipment. *Fashion and Textiles*, 1, no. 8 (2014).



the organ system, which is a collection of different organs. Finally, we reach the level of the organism, which consists of organ systems.<sup>20</sup>

The human body consists of a total of 11 organ systems, which perform all body functions with coordinated work. These are the following:

- nervous system
- reproductive system
- muscular system
- cardiovascular system
- digestive system
- endocrine system
- immune/lymphatic system
- respiratory system
- urinary system
- skeletal system
- integumentary system<sup>21</sup>

As life progresses, psychological properties change and transform. As a result of the laws of development, people of the same age show similar characteristics in terms of behaviour, thinking, and emotional experience and they also resemble each other in their way of acting. The similarity is greater at younger ages than at older ages. The common characteristics of each age group are called age characteristics. The sequence of age characteristics is irreversible, they cannot be skipped, in most individuals, they appear in the same year of life, and they follow each other. As age advances, central, essential changes, their appearance, or the lack of them, can also express the level of development and maturity.

The age-specific characteristics change after a certain time and show distinctly different characteristics from the previous one. These transformations create uniform stages of development (periodisation) that can be separated based on their characteristics. Each developmental stage includes similar physical, neurological, cognitive, emotional, behavioural and maturation stages. Unfortunately, this is not a homogeneous process, because the different psychological processes develop unevenly, and the stage boundaries are blurred. The two most important components and processes of age periodisation are biological maturation and socialisation. It should be emphasised that none of them provide the conditions for periodisation by themselves.<sup>22</sup>

In Western societies – as in our country – stereotypes related to the elderly and aging are strong. These are widely accepted beliefs about individuals belonging to different age groups, which appear for people belonging to different age groups and have an impact

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<sup>20</sup> Sarolta Darvai et al.: *Összeállítás a funkcionális anatómia tantárgyhoz csecsemő- és kisgyermeknevelő, óvópedagógus és tanító szakos hallgatók részére* [Compilation for the Functional Anatomy Subject for Students Majoring in Infant and Toddler Education, Kindergarten Teachers and Teachers]. Budapest, ELTE Tanító- és Óvóképző Kar, Természettudományi Tanszék, 2017. 10.

<sup>21</sup> Veterans Law: Human Body Organ Systems and Their Function. *Veterans Law*, 15 October 2021.

<sup>22</sup> István József: *Életheti sajátosságok és fejlődési szakaszok* [Age Characteristics and Developmental Stages]. Lecture notes, s. a.

on different areas of life. This is also true for mobile firefighters since a separate study would be worth examining the question of how the size, difficulty, density of service tasks, and the role of territorial (county) distribution are related to the appearance of age characteristics and the cumulative effects of them. The brain undergoes continuous anatomical and functional changes throughout human life. Neurological plasticity is the name given to this ability of the nervous system to change. The importance of plasticity lies in the fact that it enables the adaptation of the nervous system, together with the ability to respond to external and internal processes. The capacity for brain plasticity decreases with advancing age. The mass of the brain decreases by an average of 2–3% every ten years, which is a natural consequence of cell death observed in certain brain areas. These cells cannot regenerate, the natural process of cell death is therefore associated with a natural loss of function. The perception of the aging generation in the labour market is mostly unfavourable, which raises the question of what kind and how uniform changes are justified as the age of employees increases, and what effect does all this have on their ability to perform work? This is an extremely important factor for firefighters on mobile duty. Age-related decline can be detected in three main areas of memory processes. This is even more true for firefighters on mobile duty. One such area is the slowdown in memory processes, especially in situations where information processing and speed are important. During an intervention, performance deterioration in working memory can play a major role. A measure that is not considered in time and with insufficient thoroughness can seriously endanger the safety of life and property. Another area of decline is the necessary in-depth processing of new information, which is a consequence of the lack of cognitive control and suboptimal strategy selection. Elaboration, that is, the healthy and efficient processing of information and emotional impulses stored in our memory and subconscious mind, is damaged in this case. To manage the information appropriately, it is necessary to maintain control not only when the information is blocked, but also when it is activated, and there seems to be a decreasing trend in both control processes with aging. Another area adversely affected by aging is the retrieval of memory contents. The decline is most evident in the fact that retrieving the content requires an increased effort on the part of the person.<sup>23</sup>

According to a finding reported by Warr in 2000, there is no obvious difference between the performance of young and older workers, and the variability within the age is even greater than the average difference between ages. Warr's results are contrary to the results obtained in laboratory conditions, which primarily show deterioration of cognitive functioning. This may be due to the essential difference between the laboratory state and practical life, i.e. the world of work since the effectiveness of work is influenced by motivational and social interpersonal factors in addition to cognitive functioning. In addition, it also attempts to set up a four-factor model, based on which jobs can be categorised by taking age characteristics into account, and thus it becomes possible to determine which jobs can be recommended for older employees. The model integrates

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<sup>23</sup> Karina Ágnes Szászvári: *Fejlődés egy életen át. Az idősödő munkavállalók sajátosságai és lehetőségei* [Lifelong Development. Characteristics and Choices of the Aging Employees]. Budapest, Budapesti Gazdaságtudományi Egyetem, 2017. 8–9.

the cognitive, physical, and sometimes emotional characteristics of aging workers.<sup>24</sup> Appropriate team spirit and professional awareness can also positively influence the age characteristics of the firefighting staff on mobile duty.

Skeletal and muscular system diseases that develop in connection with special firefighting work can develop as a result of the work's special loads that do not occur elsewhere, or they can cause an aggravated condition due to the nature of the work. In the medical field, these conditions are more often called rheumatic and musculoskeletal diseases. Unfortunately, ergonomics is not given enough weight in terms of fire departments, it is not included as a specialist field in countless developments in the field, even though its application to the sub-processes affecting the work, even during the planning and implementation of firefighting techniques at the idea level, could help with so many beneficial properties during the subsequent implementation of health protection of mobile firefighters.

According to the Occupational Musculoskeletal Disorders, chronic musculoskeletal disorders are chronic problems that affect the muscles, bones, joints and soft tissues. Disorders that cannot be traced back to the exact cause, such as chronic back pain or chronic upper extremity disorders, which can occur during the execution of both firefighting and technical rescue activities, and whose exact origin can only be determined with great certainty in connection with an accident. In countless cases, the causes of these diseases can be traced back to injuries done in a forced situation or caused by one-sided loading. Rheumatic diseases and degenerative conditions, such as osteoarthritis or osteoporosis, can develop as the human body ages, possibly due to genetic predisposition or disease. Based on the European Working Conditions survey of 2010, the Hungarian situation in terms of diseases of the musculoskeletal system – that is, back, neck and upper limbs – is unfavourable even in comparison with the European Union (EU), these diseases represent significant health and outstanding cost burden. This is no different in the case of the Disaster Management since musculoskeletal diseases resulting from work are also at the top of the list of retired firefighters.<sup>25</sup> The latest European research conducted in this area also proves that diseases of the musculoskeletal system are still a significant health and cost problem, and their importance is increasing. Ensuring the physical ability of the personnel performing military service is also a very important factor in terms of preserving the ability to perform work since the physical strain resulting from service and the performance of service tasks can lead to injuries and illnesses. The result of excessive exertion or repetitive movements can be an accident or injury, which can lead to illness or, in more serious cases, loss of fitness for duty.<sup>26</sup>

Act XCIII of 1993 on labour protection in Hungary, under Section § 54 (2) of the Act, “the employer is obliged to qualitatively and, if necessary, quantitatively evaluate

<sup>24</sup> Szászvári (2017): op. cit. 22.

<sup>25</sup> Ildikó Vásárhelyi-Nagy: A beavatkozó állomány kondicionális képességei fejlesztésének új irányjai, különös tekintettel a proprioceptív módszerek alkalmazására [New Ways to Improve the Fitness Ability of the Intervening Personnel, Most Importantly with the Use of Proprioceptive Methods]. *Hadmérnök*, 13, no. 4 (2018). 411.

<sup>26</sup> Gyula Szabó: Krónikus váz-izomrendszeri megbetegedések a munkában [Chronic Musculoskeletal Diseases at Work]. *Magyar Ergonómiai Társaság*, 01 April 2021. 4–5.

the risks endangering the health and safety of employees”. Therefore, the management of ergonomic risks is also a legal requirement.

Different service groups have different health requirements, so a person unfit for one position may be perfectly fit for another. A more precise definition of the health requirements imposed on firefighting candidates is necessary for the professional use of the given agents and firefighting techniques. Protection against harmful effects occurring during firefighting work and the efficient use of human resources play an increasingly important role in everyday life. Regularised personal protective equipment that ensures safe and healthy working conditions must be available in sufficient numbers and an appropriate composition for the outgoing personnel of the fire department. During firefighting interventions – firefighting, technical rescue – this personal protective equipment plays a prominent role. The intervention at the site of the damage places extraordinary physical and ergonomic strain on the firefighter’s body – which can range from a fire that can be extinguished in 1–2 minutes to a sustained strain that lasts for several hours. The physical stress on the human body during firefighting work and its effects on the reduction of the ability to perform work is difficult to prove without conducting medical and other expert tests, but the physiological limitations of firefighter interventions in protective equipment are real problems, to reduce them, the continuous development of this personal protective equipment is justified. The measurements must be separated from the assessments for sports purposes, since maximum performance is not required during a given work, as in a sports competition.<sup>27</sup>

From an ergonomic point of view, the movement of a firefighter often consists of running, climbing, crawling, carrying loads, etc. However, a part of its functional load capacity is used by external load forms other than work, e.g. the load and heat load caused by flue gases, and poisons, as a result of which it can perform less external work. It is possible to increase this load capacity by using the most effective personal protective equipment.

With interventions using today’s modern firefighting techniques, it can no longer be stated that the firefighter can only be loaded up to the limit of his functional capacity. Ergonomics must also play a prominent role in this, since the loads on the whole body can be significantly reduced by using well-designed personal protective equipment, thus increasing functional performance. The firefighter’s protective equipment makes the wearer almost completely independent from the external environment, protecting the body from external heat effects. Factors that generally put a burden on the wearer of the protective equipment can be the following: breathing protection, the weight of the protective equipment, limited movement due to the clothing, narrowing of the field of vision, and difficulty in understanding (communication difficulties). Additional stress is caused by increased work performance and/or heat retention and heat congestion that affect the body’s heat balance due to the increase in external temperature. In addition, it is necessary to take into account possible disturbances in the body’s salt and water balance. I

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<sup>27</sup> Ferenc Kanyó – Ildikó Vásárhelyi-Nagy: A beavatkozó tűzoltói állomány kompetencia alapú fizikai állapotfelmérése [Competence-based Physical Test for Firefighters]. *Védelem Tudomány*, 6, no. 1 (2021). 207.

would also supplement this with the ergonomic stress that occurs due to work performed in a forced situation, which may lead to earlier fatigue and loss of functional performance.<sup>28</sup>

## Training of firefighters in the domestic context

In Hungary, the Disaster Management Education Centre organises the training and further training of firefighters in the area of Disaster Management. The education system has been changed from 01 January 2022, so currently it is *Firefighter Training*.<sup>29</sup> People who want to become firefighters and who have not yet dealt with firefighting apply for the Firefighter Vocational Training. During the training, they get to know both the theoretical and practical aspects of the profession, by learning about firefighting, technical rescue, the correct use of professional equipment, the proper use of personal protective equipment, communication and other law enforcement regulations.<sup>30</sup>

During the training, the future firefighters only use professional equipment, vehicles and personal protective equipment that have already been regulated.<sup>31</sup> In addition, of course, here as well as in the departments, mandatory periodical safety inspections are carried out regularly, as stipulated in Act XCIII of 1993 on labour protection, under Section § 23 (1).

## Case studies

### *International case No. 1*

Firefighters were called to a family home in a city in the United States, whose bedroom windows were open and flames were coming out. The fire chief was the first to arrive at the scene, where he was informed that the house was empty and all its residents had escaped. The crew began spraying with the syringe through the garage towards the living room. When they managed to reach the kitchen, they started towards the corridor. It was then that they saw the bedroom had almost flashed over and the flames were already overhead. While they were trying to extinguish the fire, one of the firefighters indicated that he felt burned. Shortly after, they stopped fighting the fire and left the building, after which

<sup>28</sup> Ferenc Kanyó: *A tűzoltók fizikai alkalmasságának felmérése az új évezredben, Laboratóriumi és pályavizsgáló teljesítménydiagnosztikai eljárások alkalmazási lehetőségei a tűzoltók teljesítménymérésében* [Assessing the Physical Fitness of Firefighters in the New Millennium. Application Possibilities of Laboratory and Field Testing Performance Diagnostic Procedures in Measuring the Performance of Firefighters]. Doctoral thesis. Budapest, Zrínyi Miklós Nemzetvédelmi Egyetem, 2008. 4–24.

<sup>29</sup> *Katasztrófavédelem: Szakmai képzések (2021. január 1-től indított)* [Professional Training Courses (launched from 1 January 2021)].

<sup>30</sup> Zsolt Huszka et al.: *Tűzoltói beavatkozások veszélyforrásai és munkabiztonsága* [Hazards and Occupational Safety of Firefighting Interventions]. *Védelem Tudomány*, 7, no. 2 (2022). 34.

<sup>31</sup> Regulation 15/2010 (V.12.) on the applicability of fire protection techniques related to firefighting and technical rescue activities. Regularization based on the ÖM decree: “Authorization of the unrestricted use of fire protection technology for the professional disaster prevention organization and the municipal fire department.”

another team continued to fight the fire. The burned firefighter suffered second-degree burns to his neck and ears. He was transported by ambulance to the hospital for further examination and treatment of the injury. He was only able to go back to work after nearly two months.<sup>32</sup>

In such cases, it is typical that due to the high heat load, the intervening firefighters sweat profusely, as a result of which burns occur in the areas where the personal protective equipment is less covered (i.e. the area under the strap of the breathing mask around the face). The accident could have been avoided if the firefighter had made sure that the personal protective equipment he was wearing had been put on as prescribed, and before entering the building, colleagues should have checked each other's eyes. It is also possible that the practical training is not adequate or that their repetition is not regular so that the firefighters acquire knowledge about the correct use of personal protective equipment poorly or incompletely. In addition, it is important to mention the psychological factor, since in such a case – if the firefighter is not prepared – human error can easily occur, simply due to inattention or lack of concentration.

### ***International case No. 2***

In a locality in the United States, a resident of an apartment building woke up at dawn to the sound of a smoke alarm, after which he noticed thick smoke in the living space, on the second floor. He called his roommate, who was on his way home, then went out onto the second-floor porch and called the fire department. Later investigations established that the place where the fire started was the kitchen, where newspapers and books placed too close to the stove caught fire next to the gas burner that was left alone. It was roughly thirty minutes until the room was filled with smoke, and when the resident upstairs opened the porch door, the airflow started in the smoke-filled room. In addition, the other roommate also arrived, who by opening the front door let even more air into the space in question, so the fire broke out and spread to the rest of the house. Firefighters arrived at the scene within 5 minutes of receiving the call and immediately noticed the resident trapped on the second-floor veranda and the thick smoke, which by then had completely covered the wooden house. Firefighters set up a ladder to the side of the porch and began rescuing the person stuck there. During the rescue, two firefighters suffered burns and smoke inhalation, so they had to be taken to the hospital. They were only able to perform their duties again one to three months after the incident. During the rescue, a third firefighter was also injured, he sprained his ankle, but he only received one day of relief.<sup>33</sup>

During the incident, it is believed that the injured firefighters did not wear breathing masks when they entered the smoke-filled building, so they suffered smoke poisoning. The reason for this shortcoming may be human inattention, the inadequacy of preliminary

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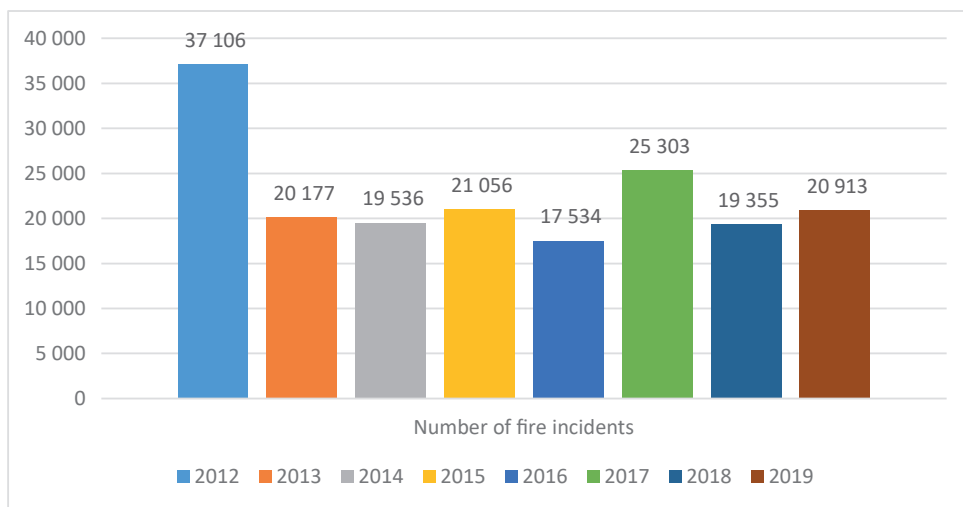
<sup>32</sup> Richard Campbell: Firefighter Injuries on the Fireground. *National Fire Protection Association*, September 2021.

<sup>33</sup> Hylton J. G. Haynes – Joseph L. Molis: U.S. Firefighter Injuries. *National Fire Protection Association*, November 2016. 27–28.

and repeated training, or professional inexperience. In my opinion, the presumed causes of burns include lack of knowledge of personal protective equipment and human inattention or distraction caused by psychological stress.

### ***Statistics in Hungary***

In Hungary, there are also many fire incidents in residential buildings, factory buildings, or even forests and fields. The number of fire incidents in 2012–2019 developed as follows (Figure 5).



*Figure 5: The number of fire incidents in Hungary between 2012–2019*

*Source: Compiled by the author based on CTIF public data.*

The number of fire incidents was almost the same except for the spike in 2017. The outliers were mainly caused by the increase in the number of outdoor fires. These data only include fire incidents, not technical rescues and other alarms. Regarding firefighting accidents in 2015–2019, the figures were as follows (Figure 6).

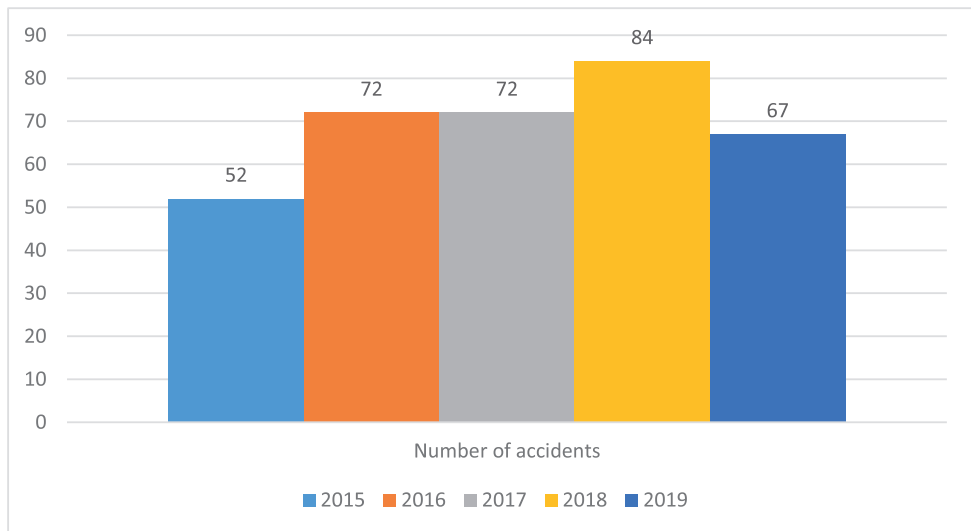


Figure 6: The number of firefighter injuries in Hungary 2015–2019

Source: Compiled by the author based on CTIF public data.

The number of injuries showed a slight increase in 2018, but not significantly. In case of accidents involving firefighters belonging to the Disaster Management, based on the available public data, the firefighting accident does not have a direct cause-and-effect relationship with the fault or failure of the personal protective equipment. Presumably, this is due to regular inspections, mandatory safety reviews, and effective training and further education.<sup>34</sup> It is likely that the data in the used source table were not entered according to uniform system of criteria, so they can probably reflect the trend for the given country, not the exact figure.

## Solutions and suggestions

Several measures can serve as a basis for maintaining and preserving the health and working capacity of firefighters suffering from chronic musculoskeletal diseases.

Maintaining appropriate safety and health protection standards and good ergonomics is an important task that can make firefighting work easier, safer, and, in some cases, healthier for all firefighters. When designing workplaces and work tools, where necessary, the role of individualised adjustments could also increase. Ergonomic improvements aimed at personal protective equipment can also help firefighters assigned to the Disaster

<sup>34</sup> Péter Pántya: A Katasztrófavédelem beavatkozó hatékonyságának fejlesztése a tűzoltósági területen [Developing the Efficiency of the Intervention Part of the Disaster Management in the Field of Fire Service]. *Hadmérnök*, 13, “KÖFOP” issue (2018). 121.



Management Authority to be able to perform their duties for a long time (decades) without harming their health.

In my opinion, it would be worthwhile to focus on prevention, that is, to intervene as early as possible, not to wait for health problems to appear, and to focus on keeping firefighters at work, not on returning them back after being out of employment.

I would also consider it important to provide continuous training in the knowledge material related to the health status of employees, as well as updating their workplace knowledge with up-to-date knowledge material regarding support for continuing work or returning to employment, specifically for human resources staff, members of the occupational health service, and occupational health and safety professionals. These measures could greatly contribute to the fact that it is easier for firefighters with impaired work ability to remain in the system, the extent of the workers' mainly physical workload is reduced, and their harmful effects can be effectively prevented and managed.

During professional training and further training, it would be recommended to use close-to-reality or mobilised version<sup>35</sup> options, which on the one hand continuously update the knowledge of firefighters, and on the other hand, the exercises could be carried out under controlled conditions, which would give more space to empirical and instrumental observation, thus the health status, as well.

Thanks to the appropriateness of the employer's attitude and the changes in the workplace, with the support of the occupational health system, many work-related diseases could be prevented, and employees with chronic diseases could continue to work under possibly easier conditions. Improving ergonomics to create better working conditions for the entire workforce can reduce sickness absence and make it easier to continue working or return to work.

In addition, I would find it useful to review the design and weight of the personal protective equipment used, as the international examples described in the article also show that the weight and design of the personal protective equipment play a key role. Clothing that fits the body, protective gloves, in which it is easier to hold the given tools, and a lightened compressed air bottle would be of great help in ensuring that the health of the person who intervenes remains high in the long term. The negative effects of climate change are currently felt by almost everyone. As a result of rainless periods and higher ambient temperatures, the number of forest and bush fires that the intervening firefighters have to fight also increases. Due to the higher outdoor temperature and the increased number of outdoor firefighting, in my opinion, it would be worthwhile to examine the material composition of the protective clothing of firefighters and to develop a new material mixture that allows firefighters to carry out interventions for a longer period, while not subjecting their bodies to as much heat stress.

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<sup>35</sup> Péter Pántya: Fire, Rescue, Disaster Management. Experiences from Different Countries. *AARMS*, 17, no. 2 (2018). 93.

## Conclusion

In the first part of the article, the reader was able to get a glimpse of typical environmental hazards, and the author also made a short detour in the area of psychological hazards. From all of this, it emerged that the intervening firefighters are exposed to very high risk during their daily work, and in this, the personal protective clothing they wear provides protection on the one hand, but on the other hand, it can even be a burden if the equipment or clothing in question is not ergonomically appropriate. After that, a brief historical background of personal protective equipment (mainly protective clothing) in the United States of America and Hungary was presented, followed by the personal protective equipment still in use today. Concerning the United States, the mistake brought out by experience, i.e. moving in a firefighters' protective helmet and breathing apparatus was highlighted.

After that, the author briefly described the human body and its structure, then detailed the relationship between load capacity and age, especially concerning the work of firefighters. In the case studies, the author described two accidents in which it can be assumed that the intervening firefighters did not use their personal protective equipment properly or that their training and further training were not effective enough for safe work. The author of the article considers it essential that both preliminary and repeated theoretical and practical training is of considerable importance, as they add to the professionally founded knowledge and skills, which are essential during interventions.

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# Causes and Effects of Uruguay's Contribution to the United Nations' Peace Operations

Andr as H ARS<sup>1</sup>

*Latin American States have been ardent defenders of international peace and security for several decades. Preeminent among them is the state of Uruguay, which has contributed a substantial amount of military and police personnel to United Nations peace operations to a degree that cannot be explained by its territory, economic potential, military might or political power. The country was lauded for its efforts in the international community by subsequent secretaries-general of the United Nations. Illustrated by the fact that the small country has provided several force commanders and thousands of personnel, Uruguay is a virtual giant when it comes to contributions to peace operations. The study aims at finding answers to three fundamental questions. Firstly, what kind of tendencies can be observed regarding the contribution of Latin American States and how Uruguay's actions can be compared to other states in the region. Secondly, what are the causes for such a robust presence. Last but not least, could large-scale contributions also have adverse effects in the form of misconduct and crimes committed by peacekeepers and if that is the case, how can such occurrences be remedied.*

**Keywords:** Uruguay, United Nations, peace operations, Latin America, contribution

## Introduction

Uruguay is often regarded as a giant when it comes to contributions to UN peace operations with the country consistently 'punching above its weight' for decades. This is especially startling since the country is located in a relatively armed conflict-free section of the globe and when the country's population is compared to those of other main contributors, the discrepancy becomes obvious. For comparison, the population of India, China, Bangladesh, Ethiopia, Pakistan, Egypt, Indonesia and Morocco are at least dozens of times larger than that of Uruguay.<sup>2</sup> Lately, however, other, smaller countries have also joined the fray, with Ghana, Nepal, Rwanda and Senegal rising to the top spots.

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<sup>2</sup> See <https://peacekeeping.un.org/en/troop-and-police-contributors>

Uruguay, however, has been an ardent supporter of this process for decades, practically speaking, ever since the UN’s creation. Understanding how this can be compared in regional context, finding the reasons of this phenomenon as well as its positive – and to some degree negative – consequences form the scope of this paper’s focus. The study aims to bring a breath of fresh air into the discussion by utilising a holistic approach which combines statistical data, historical overview, domestic and foreign policy perspectives as well as an analysis on the ramifications of these events.

## Latin American contributions to UN Peace Operations

The support Latin American States provide to UN peace operations vary greatly both in terms of financial contributions as well as regarding personnel, each having a plethora of reasons for why and to what extent they support peace missions. Generally speaking, contributions to UN peace operations can be traced back to one of five reasons (security, political, economic, institutional, normative). Along this cluster of five, general attitude and perceptions towards the United Nations as well as individual government decisions to contribute to a peace operation constitute the variables in the equation.<sup>3</sup> Political reasons range from acquiring international prestige, to supporting a bid for a non-permanent seat in the Security Council. It can be the result of international pressure from allies or even from the willingness of a country that has been the host state for operations before in order to ‘repay the favour’. For some, it can even be beneficial in domestic policy terms to make sure that the country’s oversized armed forces have something to occupy themselves with. In economic terms, a peacekeeping venture can be lucrative for both the government, private contractors and also on the level of individuals. From a security perspective, regional concerns such as migration and proximity to the conflict along with the fear that the conflict in a nearby state can spill over or spread to one’s country can propel contributions. A compelling institutional narrative can be understood as a live-action training exercise for the countries’ armed forces who can acquire valuable experience and information abroad.<sup>4</sup> A normative reasoning can stem from the country’s motives to promote the values they share with the UN or they might see the UN as a legitimate and politically ideal, neutral terrain.<sup>5</sup> On a side note, illustrating the legalist-normative approach, Latin American countries have been prone to look for judicial settlement of disputes in the past in order to avoid armed conflicts on their territories.<sup>6</sup> A remarkably positive approach when compared to states in other regions.

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<sup>3</sup> Alex J. Bellamy – Paul D. Williams: *Broadening the Base of United Nations Troop- and Police-Contributing Countries*. New York, International Peace Institute, 2012. 3.

<sup>4</sup> Bellamy–Williams (2012): op. cit. 4–5.

<sup>5</sup> Examples of altruistic motives include Canada, legitimacy reasoning can be observed regarding Ghana’s approach and counterbalancing the major powers is seen regarding India’s stance on the matter (see also Bellamy–Williams [2012]: op. cit. 5–6).

<sup>6</sup> Antonio Jorge Ramalho: Predictable Evolutions, Normative Engagements, and their Implications for South American Countries’ Engagement in Peacekeeping and Peacebuilding Operations. In Eduarda P. Hamann – Robert Muggah (eds.): *Implementing the Responsibility to Protect: New Directions for International Peace and Security?* Brasilia, Igarap  Institute, 2013. 81–82.

The tendencies above clearly manifest themselves in the Latin American context. From the point of view of state representatives, regional security challenges matter more than global issues, however, it is less clear how that unity is to be achieved. There are raging debates under the aegis of which organisation, or through aligning with which states (USA, Russia, China, India or South Africa) should such a cooperation be best reached.<sup>7</sup> One of the most notable examples to this heightened interest concerning regional security issues can be seen regarding Haiti (MINUSTAH 2004–2017).<sup>8</sup> In this instance, the financial and human contribution has far exceeded that which can be seen regarding peace operations on the African continent.<sup>9</sup> Putting the needs of the continent before the world can occur for obvious reasons as the events on the continent could have greater ramifications in the region than on the far side of the globe. Among the main perceived regional threats are transnational organised crime, poverty and management of the abundance of Latin American natural resources.<sup>10</sup> Lately, not only management but protection of natural resources,<sup>11</sup> rising numbers of human rights violations,<sup>12</sup> populism<sup>13</sup> as well as some mishandling of the Covid-19 pandemic have redirected the focus of states on the continent.<sup>14</sup> In global political terms, the issue is further exacerbated by a long-standing grievance of Latin American states, namely that the region does not have a permanent representative in the United Nations Security Council.<sup>15</sup> Despite numerous previous attempts, even the contender with the greatest chance, Brazil, remains without such a recognition of its emerging status.

A regional divide can be observed between Central American and Caribbean States on the one hand and South American States on the other. Regarding the latter, a more closely-knit articulation of interests can be seen (with the exception of Venezuela). Indeed, efforts have both increased and have become more streamlined in the southern part of the continent. This has manifested itself in stronger cooperation with regional organisations as per Chapter VIII of the UN Charter.<sup>16</sup> Prime candidates were the Organization of American States (OAS) and the Union of South American States (UNASUR). The latter

<sup>7</sup> Xenia Avezov: The New Geopolitics of Peace Operations: A Dialogue with Emerging Powers: South America Regional Dialogue. *Journal of International Peacekeeping*, 17 (2013). 163.

<sup>8</sup> Adriana Erthal Abdenur et al.: *Enhancing Peacekeeping Training through Cooperation Lessons from Latin America*. Brasilia, Igarap  Institute, 2018. 1.

<sup>9</sup> Julian Gonzalez Guyer – Nicole Jenne: Controlling Blue Berets: The Consequences of Political Neglect in the Case of Uruguay's Participation in Peacekeeping. *Armed Forces and Society*, 20 (2018). 121.

<sup>10</sup> Avezov (2013); op. cit. 169.

<sup>11</sup> Hannah White: Indigenous Peoples, the International Trend Toward Legal Personhood for Nature and the United States. *American Indian Law Review*, 43, no. 1 (2018). 139–140; Joanna J. Bryson et al.: Of, For, and By the People: The Legal Lacuna of Synthetic Persons. *Artificial Intelligence and Law*, 25 (2017). 281.

<sup>12</sup> Human Rights Watch: *Latin America: Alarming Reversal of Basic Freedoms*. 2022.

<sup>13</sup> Nicol s Cachanosky – Alexandre Padilla: Latin American Populism in the Twenty-First Century. *The Independent Review*, 24, no. 2 (2019). 214.

<sup>14</sup> Especially high numbers of fatalities can be seen regarding Peru, according to data at Johns Hopkins University (<https://coronavirus.jhu.edu/data/mortality>). Notable among these initiatives is the finding of a Brazilian commission of inquiry which has stated that President Jair Bolsonaro should be charged with crimes against humanity for his mishandling of the pandemic (Tom Phillips: Bolsonaro Should Be Charged with Crimes against Humanity, Covid Inquiry Finds. *The Guardian*, 20 October 2021).

<sup>15</sup> Avezov (2013); op. cit. 164.

<sup>16</sup> United Nations: *Charter of the United Nations*. San Francisco, 26 June 1945. Articles 52–53.

of which appeared to provide a viable alternative to the Organisation of American States (OAS) and serve as a platform of expressing shared interests; however, by 2019 most of its members have either suspended membership or withdrawn entirely, specifically Uruguay in 2020, making it *de facto* defunct.<sup>17</sup> Regional cooperation has continued nonetheless, albeit via different, mostly bilateral and *ad hoc* channels. A notable example for bilateral cooperation lies in the joint Argentinian–Chilean contingent to MINUSTAH.<sup>18</sup> Another remarkable forum for technical cooperation lies in the establishment of peacekeeping training centres and also in harmonising their training programmes.<sup>19</sup> The establishment of training centres and vetting of adequate staff cannot be overstated. As peace operations are a dynamically changing environment where adaptability is key, sharing knowledge and compiling advanced preparatory materials are becoming a crucial factor for success.<sup>20</sup> Furthermore, more robust training for police personnel, engaging with civil society, and promoting an increased role of women along with gender equality and mainstreaming are some of the fields where cooperation can be witnessed.<sup>21</sup> Indeed, military and police contributions are seen as exemplary, even though civilian contributions are seen by states in the region as insufficient. In a clear show of how different agendas can manifest themselves, Brazil has for instance taken part in the UNIFIL operation in Lebanon, reinforcing its commitment along with its belief that a maritime security focus will be a key direction for peace operations in the future.<sup>22</sup>

Overall, it can be assessed that states in Latin America have been active in UN peace operations to a varying degree, each fuelled by a combination of security, political, economic, institutional and normative interests and reasons. Directions and goals are clear and in most states in the region point towards cooperation. On a technical level, joint enterprises are working well but the continent has not found the adequate forum for cooperation. Still, general notions do not fully answer the question of why the contributions of various countries differ so much, especially in the case of Uruguay.

## The role of Uruguay

### *Uruguayan contribution in numbers*

When it comes to financial contributions, the numbers do not show anything extraordinary. Countries with larger territory, population, economic power and political influence contribute more to support the financial background of peace operations. Therefore, from a regional perspective Brazil is leading with 0.58%, followed by Argentina (0.27%),

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<sup>17</sup> El P is: Gobierno anunci  el retiro de Uruguay de la Unasur y el reingreso al TIAR [Government Announces Uruguay's Withdrawal from Unasur and Re-entry into TIAR]. *El P is*, 10 March 2020.

<sup>18</sup> Avezov (2013): op. cit. 168.

<sup>19</sup> Abdenur et al. (2018): op. cit. 2.

<sup>20</sup> Michael Kobi – Eyal Ben-Ari: Contemporary Peace Support Operations: The Primacy of the Military and Internal Contradictions. *Armed Forces and Society*, 37, no. 4 (2011). 671.

<sup>21</sup> Abdenur et al. (2018): op. cit. 3.

<sup>22</sup> Avezov (2013): op. cit. 167.



Venezuela (0.21%) and Chile (0.12%). Uruguay fits into this trend by providing an annual 0.03% financial support, while much larger states such as Colombia (0.05%), Peru (0.03%) and Ecuador (0.01%) appear equally unmotivated to contribute financially.<sup>23</sup> In this context, it does not come as a surprise that the abovementioned states from South America are not enthusiastic about financial support as on the one hand, they do not feel a regional security challenge on their territory regarding which the UN is active and on the other hand, their long-standing grievance, namely the lack of a permanent seat in the Security Council, has not been addressed.

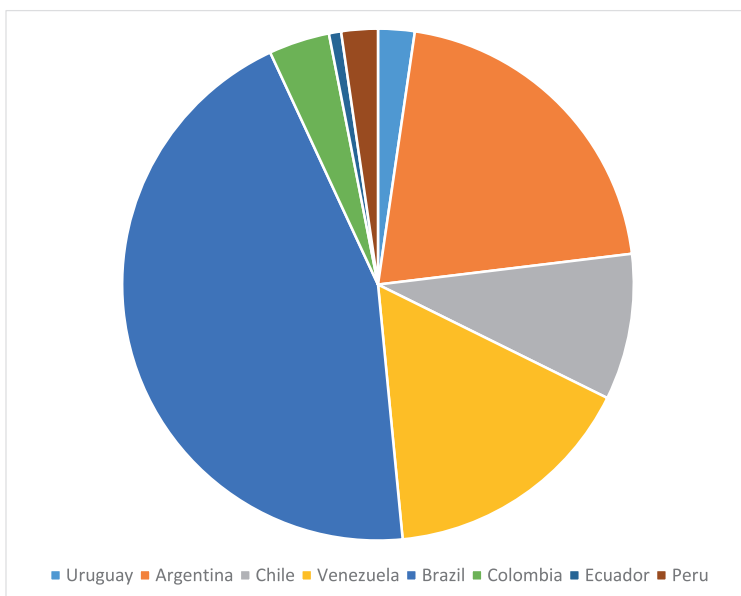


Figure 1: Major contributions from Latin American states to United Nations peace operations regarding finances (July 2021 – June 2022)

Source: Compiled by the author based on the UN's website A/73/350/Add.1, 24 December 2018.

If we look at contributions concerning personnel, a completely different picture comes to view with Uruguay's contribution amounting to an impressive 42.87% (or 1057 individuals) of the regional total. Larger than that of the five greatest – Brazil (76), Argentina (294), Peru (232), El Salvador (265) and Guatemala (176) – combined. It is a fairly common tendency that states who are 'paying with blood' will not be contributing with money, as well. Utilising this context, Uruguay will still be one of the main supporters of UN peace operations in Latin America even if the 'only' substantial aid the UN is via troops and not necessarily through money.

<sup>23</sup> UN's website A/73/350/Add.1, 24 December 2018.

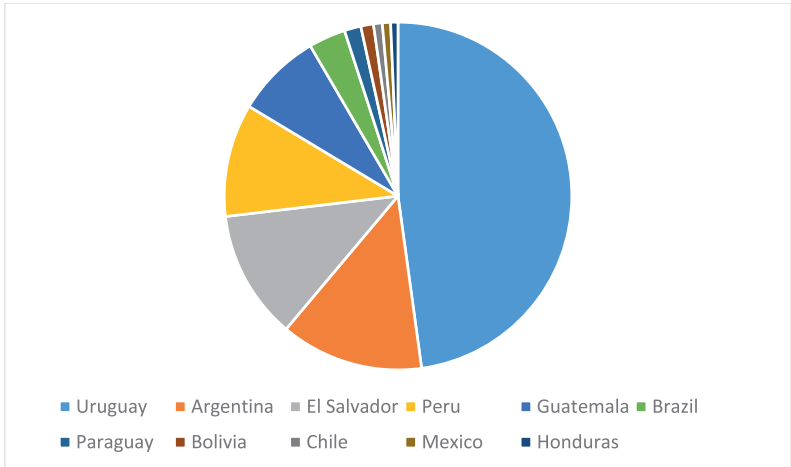


Figure 2: Contributions concerning personnel to United Nations peace operations (March 2022)

Source: Compiled by the author based on the UN's website A/73/350/Add.1, 24 December 2018.

### History and domestic background

Uruguay stands out among the states of the region from two notable perspectives. First of all, because it has been a supporter of UN peace operations right from the start and save for a few years of hiatus, provided over 45,000 troops who have been deployed to various environs, as the need dictated.<sup>24</sup> Secondly, as a mostly stable, democratic country, its domestic tranquillity served as a model for its neighbours. While this latter statement appears to paint an ideal picture, the country is not without bumps on the road when it comes to its history of democracy, nor has the relationship between the civilian government and the upper echelons of the military been ideal. A pivotal moment occurred during the period between 1973 and 1984, when President Jose Maria Bordaberry initiated a *coup d' tat* and established military-civilian rule.<sup>25</sup> The military was not only instrumental in the *coup* of 1973 but also in dismantling the military-civilian regime. Based on a compromise between senior officers and opposition leaders, amnesty was granted to the armed forces regarding their role in the previous regime. This agreement has been reinforced in later agreements, namely in 1989 and 2009,<sup>26</sup> even though the 2005 victory of Frente Amplio or the Broad Front and President Tabar  Vazquez did re-interpret the *status quo* by bringing some key supporters of the previous regimes to justice.<sup>27</sup>

<sup>24</sup> Diego Esparza et al.: Peacekeeping and Civil-Military Relations in Uruguay. *Defence and Security Analysis*, 36, no. 3 (2020). 318.  
<sup>25</sup> Esparza et al. (2020): op. cit. 318.  
<sup>26</sup> Esparza et al. (2020): op. cit. 318.  
<sup>27</sup> Guyer-Jenne (2018): op. cit. 5-6.

Some might argue that the political compromise was necessary to ensure a bloodless transition, but it did little to establish trust from the side of the local population. Subsequent presidents have therefore relied on peace operations in order to raise the standing of Uruguay’s armed forces in the eyes of the population as well as to assert civilian control over the military.<sup>28</sup> Civilian control could be measured in how the elected administration is able to exercise oversight regarding military personnel and how goals that are important for civilians are executed by the military.<sup>29</sup> In the words of Trinkunas: “Civilian control exists when politicians and bureaucrats can determine defence policies and approve military activities through an institutionalised professional defence bureaucracy”.<sup>30</sup> Uruguay has set three goals for its armed forces: protection from external sources such as Brazil and Argentina, enforcing laws and maintaining control as well as providing a rapid response regarding emergencies.<sup>31</sup> In this respect, using the money the UN provides is channelled towards training which improves all three areas. Financially speaking, participation in peace operations used to be quite a lucrative venture. Since military expenditures have been reduced drastically by the state after 1985, and especially less so since 2005, participating in UN peace operations and obtaining reimbursement from the organisation was essential for the armed forces.<sup>32</sup> However, as recent studies show, peacekeeping is only a lucrative venture for states under special circumstances and previous assumptions on how GDP per capita can be directly linked to contributions have been refuted by in-depth data analysis.<sup>33</sup> Taking part in robust peacekeeping and peacebuilding ventures also builds experience in how to maintain control over a territory and engage multiple actors. Exposing part of the armed forces to unpredictable environments and building a problem-solving capacity that can be relied upon in emergencies at home can also be considered to be an asset.

Changing perceptions from soldiers to peacekeepers has reinforced this positive change.<sup>34</sup> In some ways, this ‘rebranding’ of military forces and shifting their role in society was successful. From a societal standpoint, sending soldiers abroad has improved the perception of the military by society, transforming the general notions of a soldier maintaining military rule in the country to that of a peacekeeper working to aid those in dire situations abroad. It is hard to measure the perceptions of the general population and there is a debate among scholars as to the extent of changed perception in society.<sup>35</sup> Civilian oversight is not exactly an ideal situation. As some scholars point out, there is a palpable lack of interest from civilian governments and administrators regarding military matters. As a result, on the one hand, the military has retained considerable autonomy, but on the other hand, they do not receive sufficient funds to support their own

<sup>28</sup> Esparza et al. (2020): op. cit. 318–319.

<sup>29</sup> Esparza et al. (2020): op. cit. 319.

<sup>30</sup> Harold A. Trinkunas: *Crafting Civilian Control of the Military in Venezuela. A Comparative Perspective*. Chapel Hill, University of North Carolina Press, 2011. 58.

<sup>31</sup> Esparza et al. (2020) op. cit. 323.

<sup>32</sup> Am lcar Andr s Pel ez: Country Survey XX: Defence Spending and Peacekeeping in Uruguay. *Defence and Peace Economics*, 18, no. 3 (2007). 297.

<sup>33</sup> Katharina P. Coleman – Benjamin Nyblade: Peacekeeping for Profit? The Scope and Limits of ‘Mercenary’ UN Peacekeeping. *Journal of Peace Research*, 55, no. 6 (2018).

<sup>34</sup> Esparza et al. (2020) op. cit. 326.

<sup>35</sup> See also Esparza et al. (2020): op. cit. versus Guyer–Jenne (2018): op. cit.

agenda.<sup>36</sup> Consequences of this can be seen concerning the status of the aerial capacities of Uruguay, which is rapidly becoming out-of-date, expensive to maintain and prone to accidents.<sup>37</sup> Indirectly, the lack of funds can also end in lower intensity participation in peace operations as lacking funds for equipment at home will mean fewer forces that can reliably be sent abroad.

From a historical perspective, there has been continuous support for peace operations since 1952, albeit for the first decades, sending military observers abroad was the largest contribution of Uruguay to UN missions. The most visible of these have been deployment in the Sinai Peninsula and border surveillance until 1988 during the Iraq–Iran war. In the 1990s, Uruguay has been an active participant in the second generation peace operations in Cambodia, Mozambique and Angola with an increased number of personnel when compared to previous operations. Since the 2000s, the country has had a robust contribution to the operations in Haiti<sup>38</sup> and the Democratic Republic of the Congo.<sup>39</sup> At its peak between 2006 and 2010, between a quarter and a third of the country's armed forces have been engaged in United Nations peace operations at a given time.<sup>40</sup> After around 2010, the tendencies appear to have been shifting with Uruguay downsizing its contributions. From an all-time high between the years 2007 and 2010 of roughly 2,500 personnel, lately, the country has been sending between altogether 1,000–1,100 personnel by 2022. Nonetheless, Uruguay remains among the top 20 contributors and the most ardent supporter of UN peace operations in a regional context, even though it has been dethroned from the absolute top of the pyramid.<sup>41</sup>

### ***Tangible results and foreign policy perspectives***

Some results of such a continuous and strong cooperation can be seen in various fields. As mentioned before, the country houses a key training centre where experiences can be shared not only with Uruguayan forces but based on bilateral and regional agreements, with other partners as well. It can also be stated/declared that Uruguay is being recognised for its efforts by the UN itself, not only through public displays of support, but also by allowing the country and its citizens to fill key leadership roles.<sup>42</sup> A prime example can be observed in the case of Major General Jos  Eladio Alca n, who has been leading the observer mission between India and Pakistan (UNMOGIP) since 2018.<sup>43</sup> A cautionary

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<sup>36</sup> Esparza et al. (2020) op. cit. 330.

<sup>37</sup> Esparza et al. (2020) op. cit. 324.

<sup>38</sup> Juli n Gonz lez Guyer: Punching above Its Weight. Uruguay and UN Peace Operations. In Kai Michael Kenkel (ed.): *South America and Peace Operations. Coming of Age*. London, Routledge, 2013. 115.

<sup>39</sup> Franz Kernic – Lisa Karlborg: Dynamics of Globalization and Regional Integration: South America and Peace Operations. *International Peacekeeping*, 17, no. 5 (2010). 725.

<sup>40</sup> Kai Michael Kenkel: Stepping out of the Shadow: South America and Peace Operations. *International Peacekeeping*, 17, no. 5 (2010). 589.

<sup>41</sup> See <https://peacekeeping.un.org/en/troop-and-police-contributors>

<sup>42</sup> Uruguay lauded by the UN Secretariat (<https://news.un.org/en/story/2018/02/1003401>).

<sup>43</sup> UNMOGIP leadership (<https://unmogip.unmissions.org/leadership>).

approach is warranted though at this point as Uruguay’s emerging role is not to be confused with a dominant position which the country does not hold in the UN.

Moral support for the liberal world order is a constant theme in the country’s foreign policy agenda. Since Uruguay was one of the founders of the League of Nations after the First World War and also has supported the United Nations since its creation, it can be established that the country has a long history of promoting multilateralism. Uruguay has also been actively campaigning for seats in the UN Security Council. In the highly competitive Latin American context, it has managed to win non-permanent seats twice, in 1965–1966 and 2016–2017 respectively.<sup>44</sup> Foreign policy perspectives can also be aligned along the lines of self-determination and non-intervention with a focus on peaceful dispute resolution. As Guyer points out, this political leaning is not only due to an interest in maintaining the norms set out by the United Nations but also because of the country’s location as a buffer between Argentina and Brazil and its history of navigating the waters between two much larger states.<sup>45</sup> These notions are reflected in the speeches before the UN General Assembly. The latest of these addressed by President Luis Lacalle Pou in 2021 has highlighted support of democratic values and individual freedoms, taking a stand against human rights violations, promoting the principle of non-intervention, the freedom of trade, and “protection that did not become protectionism”.<sup>46</sup> The latter statement is a breath of fresh air and can be understood in the context of several countries’ refusal to share Covid vaccination stockpiles. It can, however, also be translated as a warning that there was the weakening of the multilateral framework over the course of the last two years in favour of singular promotion of state interests – ideas which are contrary to the foreign policy agenda of Uruguay, which remains a staunch supporter of the international system and the United Nations.

### *Negative consequences*

Sending a large number of troops to peace operations also raises the chance for misdemeanours or crimes to be committed during the mission. As a result, some negative consequences will also need to be drawn attention to. In 2011, during the MINUSTAH operation in Haiti, news has surfaced that Uruguayan soldiers were involved in sexual exploitation and abuse (SEA) against locals.<sup>47</sup> SEA is unfortunately not a rare phenomenon in UN peace operations and wherever it sprouts, victims suffer, the mission’s goals and the reputation of the organisation are jeopardised and if it meets with a lack of accountability, a sense of impunity can spread which can seep into the military system of the sending state. In 2011, when Uruguayan peacekeepers were involved, President Jos  Mujica has issued an apology and promised to conduct a full-scale investigation in order to bring the perpetrators to justice. Indeed, three separate investigations were conducted: one by the

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<sup>44</sup> Non-permanent seats of Uruguay ([www.un.org/securitycouncil/content/uruguay](http://www.un.org/securitycouncil/content/uruguay)).

<sup>45</sup> Guyer (2013): op. cit. 113.

<sup>46</sup> Official record of the 76<sup>th</sup> session, 6<sup>th</sup> plenary meeting, A/76/PV.6, 22 September 2021.

<sup>47</sup> Guyer (2013): op. cit. 113.

Defence Ministry of Uruguay, the second by Haiti and the third by the UN.<sup>48</sup> However, due to states exercising exclusive jurisdiction in criminal matters committed by their peacekeepers, the sole investigation which could have resulted in adequate justice in the form of a prison sentence could only be done by Uruguay. Indeed, the state has conducted the investigation, but as the allegations could not be substantiated due to the fact that the victim could not be traced, the five alleged perpetrators were released.<sup>49</sup> Nonetheless, it had internal ramifications domestically. As Guyer has put it: “[the case] not only placed a focus on the conduct of Uruguayan soldiers abroad, but led to a strong questioning of military education methods and institutional culture, as well as highlighting civilian sins of omission regarding democratic control”.<sup>50</sup> Since then, we can see that SEA continues to exist with Uruguayan peacekeepers continuing to be implicated while steps are also taken to combat the phenomenon. In 2017, Secretary-General Ant nio Guterres has praised Uruguay for appointing a national investigative officer quickly: within 5 days of notification of the allegation. It has also been highlighted that the country has cooperated well with the Secretariat and the Office for Internal Oversight Services responsible for handling the allegations within the UN. It was shared as a ‘best practice’ that Uruguay was the first state not only to set up a focal point for paternity claims but establishing a whole protocol on the role of the focal point.<sup>51</sup> Even so in 2017, 8 peacekeepers from Uruguay have been accused of engaging in transactional sexual relations with 2 local beneficiaries of assistance which fall under the category of SEA but the allegations were ‘unsubstantiated’ as the investigation has concluded.<sup>52</sup> In 2019, an allegation has surfaced where an Uruguayan peacekeeper has engaged in an exploitative relationship with a local.<sup>53</sup> In 2020, a case concerning rape against a minor was reported.<sup>54</sup> Whereas in 2021, an exploitative relationship concerning transactional sex has allegedly taken place with an adult victim that resulted in a paternity claim.<sup>55</sup> As it can be deduced from the information disclosed by the Secretariat, Uruguay is responsive towards claims of SEA and communicates well with the UN, even though it has not managed to effectively eliminate serious misconduct and crimes committed by its peacekeepers.

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<sup>48</sup> Al-Jazeera: Uruguay Apologises over Alleged Rape in Haiti. *Al-Jazeera*, 07 September 2011.

<sup>49</sup> PeaceWomen: Haiti: U.N. “Outraged” at Sexual Abuse by Peacekeepers. *IPS*, 23 January 2012.

<sup>50</sup> Guyer (2013): op. cit. 113.

<sup>51</sup> Special measures for protection from sexual exploitation and abuse: a new approach, Report of the Secretary-General, A/71/818, 28 February 2017.

<sup>52</sup> Special measures for protection from sexual exploitation and abuse, Report of the Secretary-General, A/72/751, 15 February 2018, Allegations reported to the Office of Internal Oversight Services in 2017 involving civilian personnel in peacekeeping and special political missions, by field mission (as at 31 December 2017).

<sup>53</sup> Special measures for protection from sexual exploitation and abuse, Report of the Secretary-General, A/74/705, 17 February 2020, Allegations involving military personnel, by field mission.

<sup>54</sup> Special measures for protection from sexual exploitation and abuse, Report of the Secretary-General, A/75/754, 15 February 2021, Allegations involving military personnel, by field mission.

<sup>55</sup> Special measures for protection from sexual exploitation and abuse, Report of the Secretary-General, A/76/702, 15 February 2022, Allegations involving military personnel, by field mission.

## Concluding remarks

When compared to contributions from other Latin American States, Uruguay does indeed stand out as one of the largest supporters of UN peace operations when it comes to personnel but necessarily regarding finances. Even though the number of personnel has decreased significantly since its peak in 2010, Uruguay's support remains constant for the organisation and towards the maintenance of international peace and security. The reasons for this exceptional contribution are manifold. On the one hand, it is caused by the economically feasible nature of the venture and the political benefits through which a country of less than 3.5 million can have a loud voice in international affairs. On the other hand, Uruguay's activity in the field is also influenced by regional security challenges, as seen regarding its leading role in the MINUSTAH operations. The support is also due to traditions, as Uruguay has been involved in peaceful settlement of disputes since 1936 and has had a continuous presence in peace operations since 1952. It is also due to the country's (and its populations' as well as its elected leaders') belief in the altruistic mission of the United Nations. Despite political populism becoming widespread on the continent and the extraordinary challenges brought by the Covid-19 pandemic, Uruguay's liberal and cooperative outlook on international affairs remains constant. Providing a task for its comparatively large military as well as shaping a softer, more humane image for the armed forces has substantially underlined Uruguayan presence in peace operations. No coin is without a flip-side, however. In this case, it is somewhat of a necessity for the military to support its revenues by engaging in peace operations as support from the state remains wanting. Another field where the possibilities are not used to their fullest extent, is civilian oversight, which was established since the change of regime, but effective control and policy-level reforms remain to be seen. Due to the lack of interest concerning oversight, sexual exploitation and abuse has also proven to be a phenomenon that continues to persist despite continued attempts to stem its recurrence. Overall, Uruguay remains a beacon of cooperation and devotion towards a multilateral world order in a Latin American context, even though room for improvement exists when it comes to transparency regarding domestic process for crimes committed in peace operations and stronger civilian oversight exerted over the armed forces.

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# Examination of Vegetation Fire Spread with Numerical Modelling and Simulation Using Fire Dynamic Simulator

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*Nowadays, the number of forest and vegetation fires is gradually increasing, which are destroying ever larger areas of the Earth. In order to increase the efficiency of activities aimed at prevention and elimination of the consequences of fires, a scientifically based investigation of vegetation fires is essential. Our goal is to examine vegetation fires in simulation environment. During our research work, a simulation model was created with WFDS program, and the spread and effects of fire in a given area were examined. The analysis of the simulation results can help in understanding the propagation properties of vegetation fires, as well as form a good starting point for further research.*

**Keywords:** forest and vegetation fire, fire spread, firefighting, numerical simulation, fire prevention

## Introduction

Outdoor fires arising as a result of global climate change, especially forest and vegetation fires depending on location and extent, can cause serious damage to the natural and built environment, and their ecological destruction is slowly regenerated.<sup>5</sup> In the event of a large-scale vegetation fire, not only the vegetation living in the area is damaged, but the environment also suffers a significant load; therefore, accurate knowledge of the fire spread processes plays an important role in prevention and firefighting. One possible way to investigate fire spread is modelling and computer simulations. Modelling forest and vegetation fires is a complex process, as many non-linear interactions take place in space

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<sup>5</sup> József Padányi – László Földi: Security Research in the Field of Climate Change. In László Nádai – József Padányi (eds.): *Critical Infrastructure Protection Research. Results of the First Critical Infrastructure Protection Research Project in Hungary*. Zürich, Springer International Publishing, 2016. 79–90.

and time.<sup>6</sup> Physics-based modelling approximates fire behaviour using CFD<sup>7</sup> methods, numerically solving 3D time-based equations.<sup>8</sup> Vegetation fires can be divided into three groups according to the way they spread: ground, surface and canopy fires.<sup>9</sup> According to another grouping, there are also plume-driven and wind-driven vegetation fires.<sup>10</sup> The aim of the authors of this paper is to carry out case studies in simulation environment, taking into account Hungarian parameters, after a theoretical overview of vegetation fires. We consider it important to test a program suitable for the simulation of vegetation fires, as well as to facilitate the practical use of the results.

## Examination of vegetation fires

After reviewing the available literature sources, it was found that several studies dealt with the investigation of forest and vegetation fires, which provides a good starting point for our work. The combustion of pine trees of different sizes and moisture content was investigated in a simulation and in a laboratory environment by William Mell et al.<sup>11</sup> Mass loss and changes in heat flux were monitored. The simulation and measurements were similar. In the paper of Chad Hoffman et al., the risk of trees being attacked by bark beetle was investigated in the case of canopy fires.<sup>12</sup> Randomly generated layouts and mortality rates were used. It was shown that the mortality rate had the greatest effect on the burning of trees. Fuel consumption and canopy fire intensity were also investigated. In the publication of Rodman Linn et al., we can read about 5 physics-based simulation models, 4 of which take into account idealised conditions, and the fifth takes into account realistic meteorological conditions and non-homogeneous vegetation.<sup>13</sup> The influence of the environment on fire was investigated using the FIRETEC program. The publication of Nicolas Frangieh et al. deals with grassland fires.<sup>14</sup> The rate of fire spread, and the intensity of fire were examined in the case of different wind speeds. In case of low wind speeds, the simulation approximated the experiment well. It was also shown that fire ignition greatly affects the shape of the fire front without changing the rate of fire spread. It was found that low-speed wind does not significantly affect the spread of the fire. However, a higher wind

<sup>6</sup> Chad M. Hoffman et al.: Advancing the Science of Wildland Fire Dynamics Using Process-Based Models. *Fire*, 1, no. 2 (2018).

<sup>7</sup> CFD: computational fluid dynamics.

<sup>8</sup> Chad M. Hoffman et al.: Evaluating Crown Fire Rate of Spread Predictions from Physics-Based Models. *Fire Technology*, 52 (2016). 221–237.

<sup>9</sup> William Mell et al.: Numerical Simulation and Experiments of Burning Douglas Fir Trees. *Combustion and Flame*, 156, no. 10 (2009). 2023–2041.

<sup>10</sup> Andrew L. Sullivan: Convective Froude Number and Byram's Energy Criterion of Australian Experimental Grassland Fires. *Proceedings of the Combustion Institute*, 31, no. 2 (2007). 2557–2564.

<sup>11</sup> Mell et al. (2009): op. cit.

<sup>12</sup> Chad Hoffman et al.: Numerical Simulation of Crown Fire Hazard Immediately after Bark Beetle-Caused Mortality in Lodgepole Pine Forests. *Forest Science*, 58, no. 2 (2012). 178–188.

<sup>13</sup> Rodman Linn et al.: Studying Wildfire Behavior Using FIRETEC. *International Journal of Wildland Fire*, 11, no. 4 (2002). 233–246.

<sup>14</sup> Nicolas Frangieh et al.: Numerical Simulation of Grassland Fires Behavior Using an Implicit Physical Multiphase Model. *Fire Safety Journal*, 102 (2018). 37–47.

speed significantly increases the depth of the fire front. Fire intensity was calculated based on Byram's theory taking into account vegetation mass loss and heat release rate. In the publication of Dominique Morvan and Jean-Luc Dupuy, we can read about a multiphase outdoor fire spread in case of a Mediterranean shrubland.<sup>15</sup> A finite number of fuels were defined as a multiphase approach. The 2D calculations were performed in a flat area assuming that the shape of the fire front is straight. In case of wind, the initial line of the fire front changed to a parabolic shape. It was found that the shape of the flame is almost vertical in case of low-speed winds. In case of a stronger wind, the airflow is diluted in the plume, and the hot flames cool down above the combustion zone, thereby reducing the height of the flame. Correlations between flame spread rate and wind speed were also investigated. The Hungarian experience of extinguishing forest and vegetation fires so far<sup>16</sup> and the data of aerial reconnaissance<sup>17</sup> also provide a good starting point for creating the model and determining the boundary conditions of the simulation.

## Simulation model

For the simulations, the Wildland Urban Interface Fire Dynamic Simulator (WFDS) program was used, which is an extension of the Fire Dynamic Simulator (FDS). It is primarily used to simulate wildland fires and structural fires.<sup>18</sup> WFDS numerically solves the Navier-Stokes equations for low Mach-number flow and models turbulent dissipation using a large-eddy simulation approach. This approach results in space- and time-dependent predictions of fire behaviour characterised by transient heat flux (radiative and convective) and takes into account heterogeneous fuel complexes and fuel–fire–atmosphere interactions.

WFDS offers different simulation models for wildfires, which are the particle model, the boundary fuel model and the level set model. The program also includes a pyrolysis model developed specifically for vegetation fires. Vegetation is made up of particles with different properties such as surface area/volume ratio, moisture content, density and volume fraction. The model takes into account the interaction between living and dead vegetation. The multiphase reaction includes both the vegetation and the resulting gases. The increase in temperature first causes the evaporation of the water and then of the dry matter, during which combustible gases are produced, and then the remaining solid fuel turns into charcoal. Particles can be described based on the mass percentage of water,

<sup>15</sup> Dominique Morvan – Jean-Luc Dupuy: Modeling the Propagation of a Wildfire through a Mediterranean Shrub Using a Multiphase Formulation. *Combustion and Flame*, 138, no. 3 (2004). 199–210.

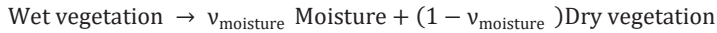
<sup>16</sup> László Földi – Rajmund Kuti: Characteristics of Forest Fires and their Impact on the Environment. *AARMS*, 15, no. 1 (2016). 5–17.

<sup>17</sup> Ágoston Restás: *Az erdőtüzek légi felderítésének és oltásának kutatás-fejlesztése* [Research and Development of the Aerial Reconnaissance and Extinguishing of Forest Fires]. PhD thesis. Budapest, Zrínyi Miklós National Defence University, Bolyai János Faculty of Military Engineering, Doctoral School of Military Technology, 2008.

<sup>18</sup> Chad M. Hoffman et al.: Surface Fire Intensity Influences Simulated Crown Fire Behavior in Lodgepole Pine Forests with Recent Mountain Pine Beetle-Caused Tree Mortality. *Forest Science*, 59, no. 4 (2013). 390–399.

dry matter, charcoal and ash. The solid phase thermal decomposition process of general vegetation consists of three reactions:<sup>19</sup>

1. Endothermic moisture evaporation



$$v_{\text{moisture}} = \frac{M}{1 + M}$$

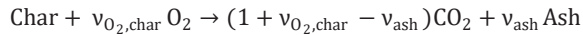
where  $v_{\text{moisture}}$  is the moisture content,  $v_{\text{moisture}}$  is the mass fraction of the moisture.

2. Endothermic pyrolysis of dry vegetation



where  $v_{\text{char}}$  is the mass fraction converted to char during pyrolysis.

3. Exothermic charcoal oxidation



where  $v_{\text{O}_2, \text{char}}$  is the mass of oxygen consumed per unit mass of char oxidised and  $v_{\text{ash}}$  is the mass fraction of char that is converted to ash during char oxidation.

The simulation is physical model-based.<sup>20</sup> The particles model foliage and branches of different sizes. The material properties were also given based on the literature.<sup>21</sup> The reaction gas was cellulose. The height of the shrubs is 3 m. The ambient temperature was 20°C. The terrain is flat, there are no slopes. The mesh size was 0.5 × 0.5 × 0.5 m. The moisture content of the wooden materials was 0.49.

Five simulation cases were examined:

1. there are only shrubs, there is no wind
2. there are only shrubs, there is 5 m/s wind
3. there are only shrubs, the height of the shrubs is 1 m
4. there are only shrubs, the moisture content is 0.1
5. there are some trees with random generated placement

The simulation models are shown in the figure below.

<sup>19</sup> Kevin McGrattan et al.: Fire Dynamics Simulator User's Guide. *NIST Special Publication 1019*, 2022.

<sup>20</sup> William Mell et al.: A Physics-Based Approach to Modelling Grassland Fires. *International Journal of Wildland Fire*, 16, no. 1 (2007), 1–22.

<sup>21</sup> Mell et al. (2009): op. cit

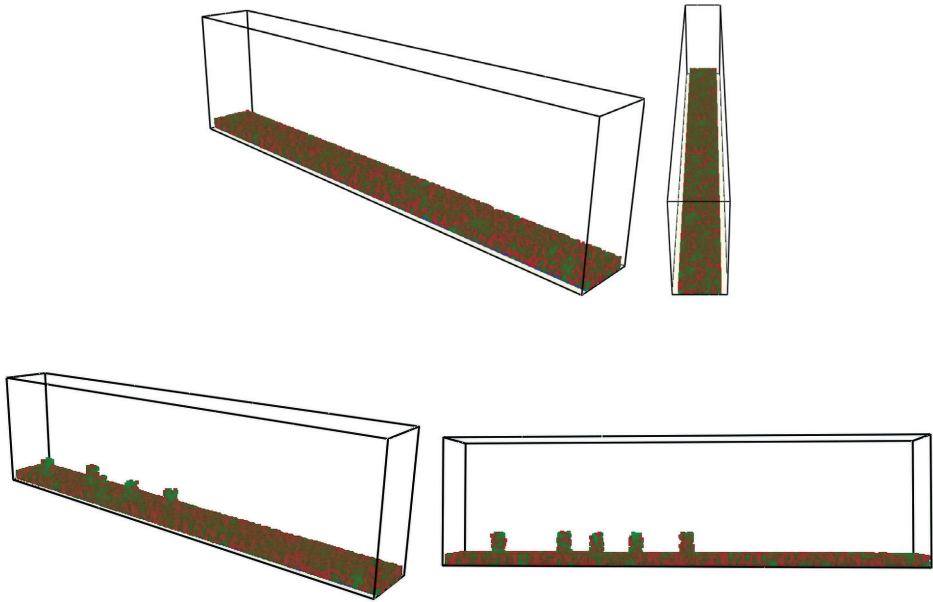


Figure 1: Simulation models (up: shrubs only, down: there are also trees)

Source: Compiled by the authors.

The burnable area is  $150 \times 18 \times 40$  m. There is a road on both sides of the area. The speed of the fire spread was determined to be 3 m/min. with starting point 75; 2.1; 0. The heat release rate per unit area (HRRPUA) value of the fire is shown in Figure 2.

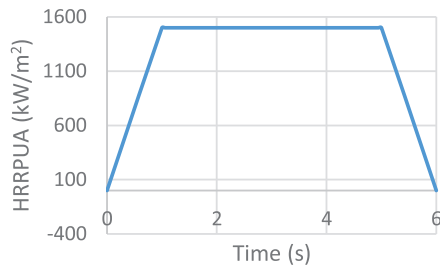


Figure 2: Heat release rate per unit area of the fire

Source: Compiled by the authors.

The simulation time was 900 s. The simulation ran in parallel using MPI and OpenMp.

## Results

Before examining the cases, it was analysed how the width of the non-combustible part (road) affects the simulation. The fire spread (HRRPUV<sup>22</sup>) and the heat flux were examined at 200 s, 350 s, and 900 s (Figures 3–5) in case of different road widths.

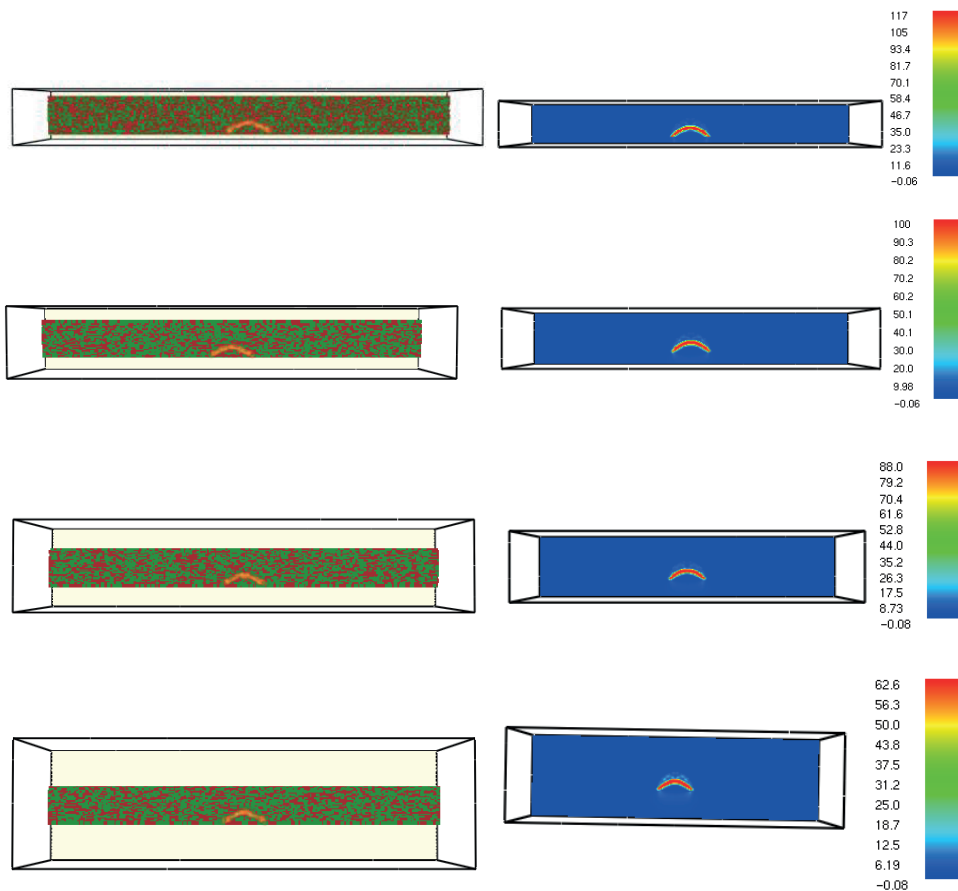


Figure 3: HRRPUV and heat flux ( $\text{kW/m}^2$ ) at 200 s (from top to bottom 2 m, 5 m, 8 m, 16 m)

Source: Compiled by the authors.

<sup>22</sup> HRRPUV: Heat release rate per unit volume.



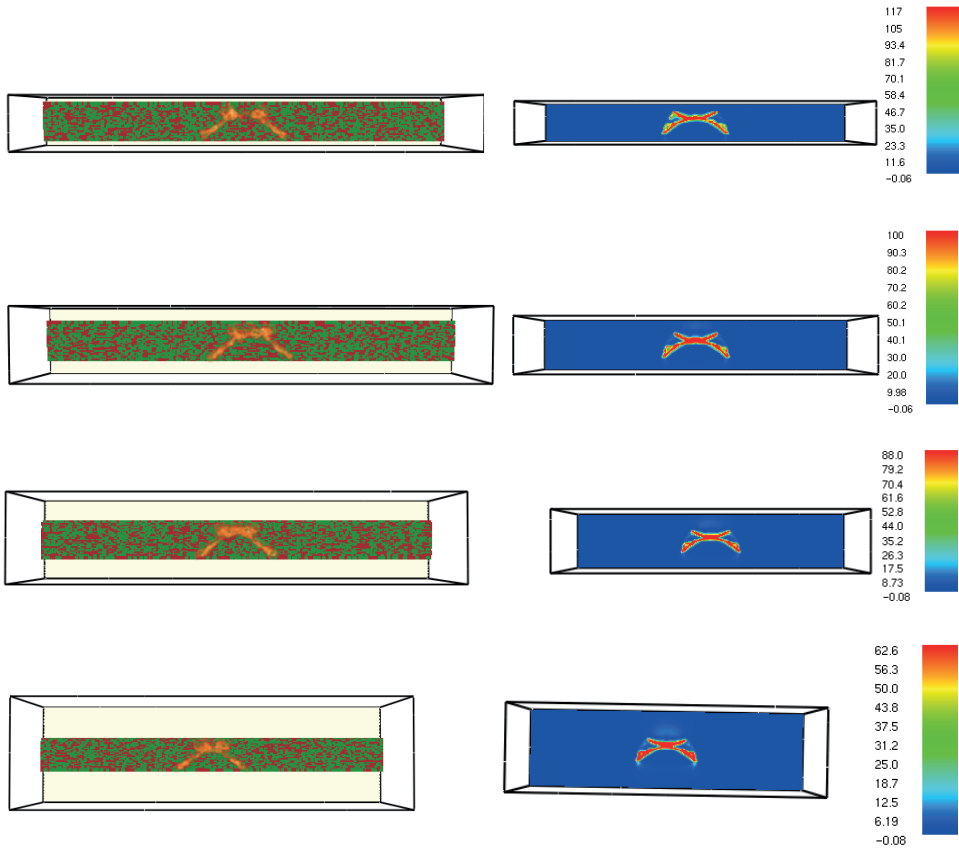


Figure 4: HRRPUV and heat flux ( $\text{kW/m}^2$ ) at 350 s (from top to bottom 2 m, 5 m, 8 m, 16 m)

Source: Compiled by the authors.

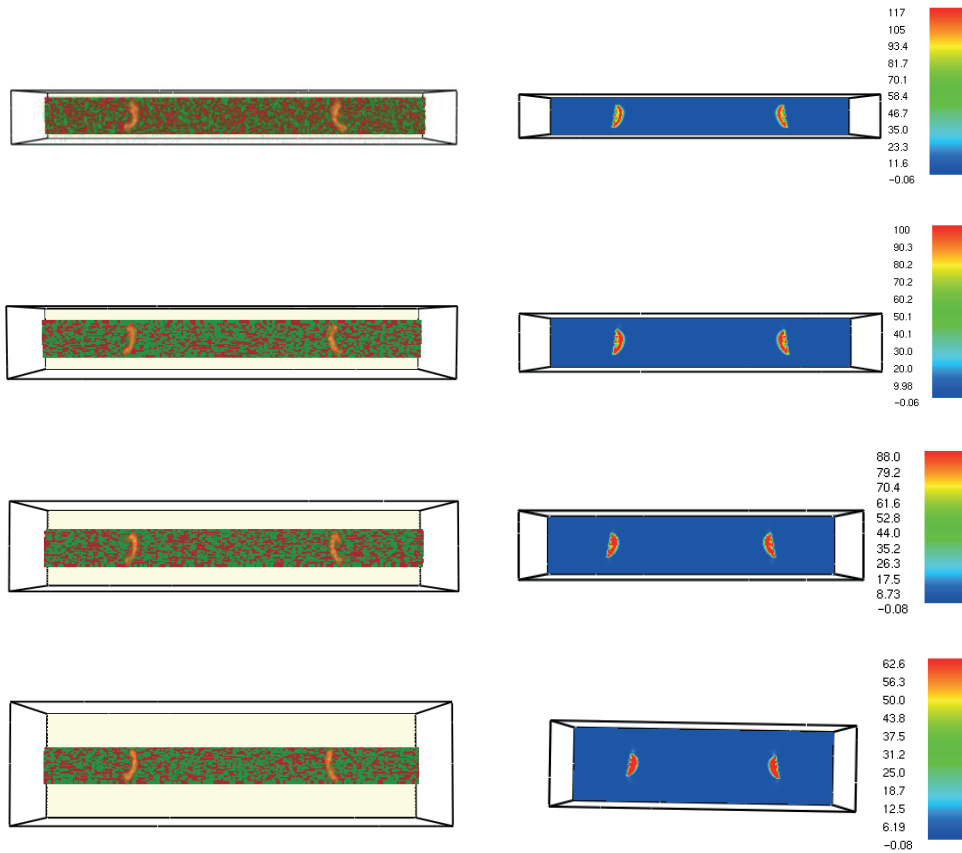


Figure 5: HRRPUV and heat flux ( $\text{kW/m}^2$ ) at 900 s (from top to bottom 2 m, 5 m, 8 m, 16 m)

Source: Compiled by the authors.

It can be seen that the HRRPUV figures developed similarly. However, at 350 s, when the fire plume reaches the other side, there is a difference. There is also a difference in the maximum value of the heat flux. The value of the heat release rate (HRR) was also examined (Figure 6).

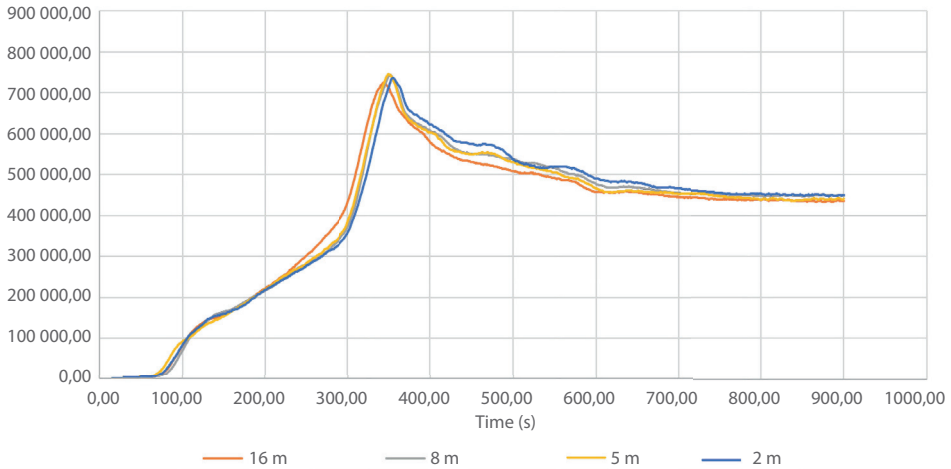


Figure 6: Heat release rate (HRR)

Source: Compiled by the authors.

It can be seen that there is a difference between the individual HRR curves. Between the 8 m and 5 m curves, the difference is minimal. The value of the HRR is initially 0, followed by a rising section, then reaches a maximum and begins to decrease, and finally settles to a constant value. There is a greater difference between the curves in the increasing and decreasing sections.

The calculation time of the simulations was also examined (Table 1).

Table 1: Calculation time of the simulations

Road width	2 m	5 m	8 m	16 m
Calculation time	14 h	17 h	17 h	25 h

Source: Compiled by the authors.

It can be seen that the 5 m and 8 m wide roads do not significantly increase the calculation time of the simulation. However, the 16 m wide road significantly increases the calculation time. Therefore, we performed the simulations with the 8 m wide road.

From Figures 2–4 we can get information about the spread of the fire. At 200 s, the fire front has a parabolic shape, which becomes wider as time goes by. At about 350 s, the fire reaches the other side, and then it splits in two directions. After that, the fire spreads symmetrically in a parabolic shape.

The rate of fire spread (ROS) is calculated as follows.

Before splitting in y direction:

$$ROS = \frac{y}{t} = \frac{14}{358} = 0.039 \text{ m/s}$$

Before splitting in x direction:

$$ROS = \frac{x}{t} = \frac{15}{358} = 0.042 \text{ m/s}$$

After splitting in x direction:

$$ROS = \frac{x_2 - x_1}{t_2 - t_1} = \frac{44 - 15}{900 - 358} = 0.05 \text{ m/s}$$

ROS can be calculated similarly in the other cases as well. A summary of ROS is shown in Table 2.

The fire spread and heat flux in the second case is shown in Figure 7.

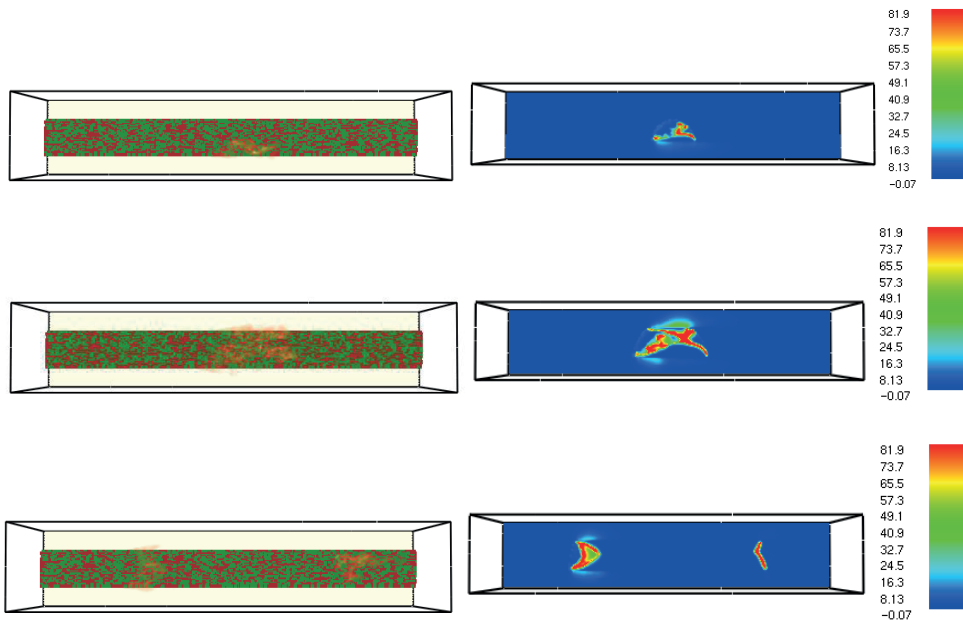


Figure 7: HRRPUV and heat flux ( $\text{kW/m}^2$ ) in the second case (top: 200 s, middle: 350 s, bottom: 900 s)

Source: Compiled by the authors.

It can be seen that the fire spreads more in the direction of the wind. After separation, it primarily spreads in the direction of the wind, but it also spreads in the other direction as well. The direction of the wind can also be observed on the heat flux: a wider flux can be seen on the left side, and a narrow but more intense flux can be observed on the right side.

The fire spread and heat flux in the third case is shown in Figure 8.

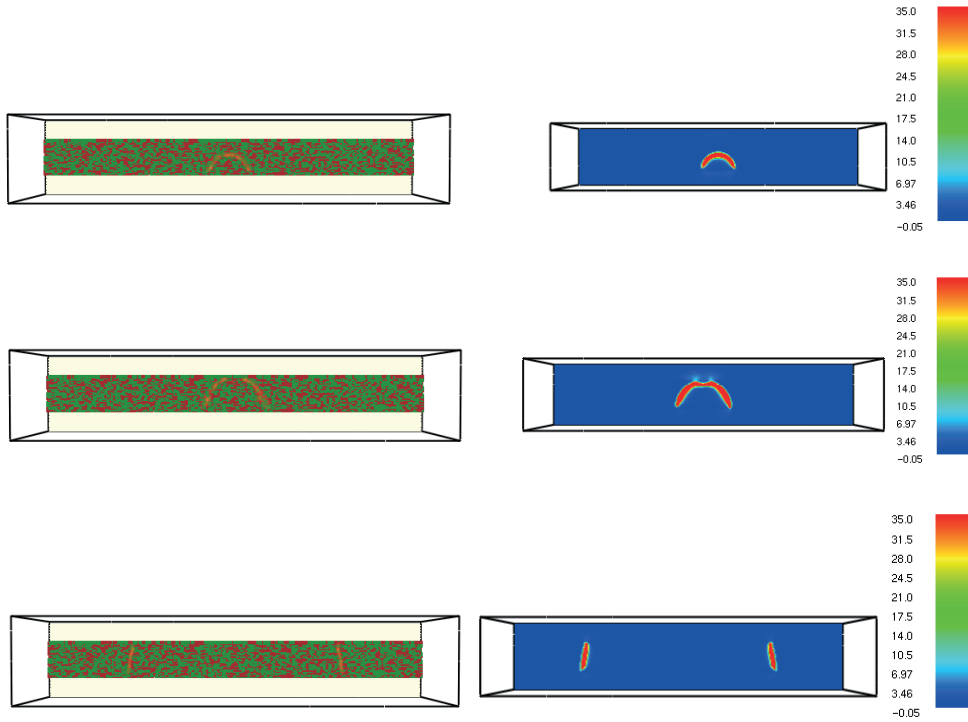


Figure 8: HRRPUV and heat flux ( $\text{kW/m}^2$ ) in the third case (top: 200 s, middle: 295 s, bottom: 900 s)

Source: Compiled by the authors.

The fire reaches the other side at about 295 s. It can be seen that the fire spreads faster, but the fire plume is much narrower. The maximum value of the heat flux is also lower.

The fire spread and heat flux in the fourth case is shown in Figure 9.

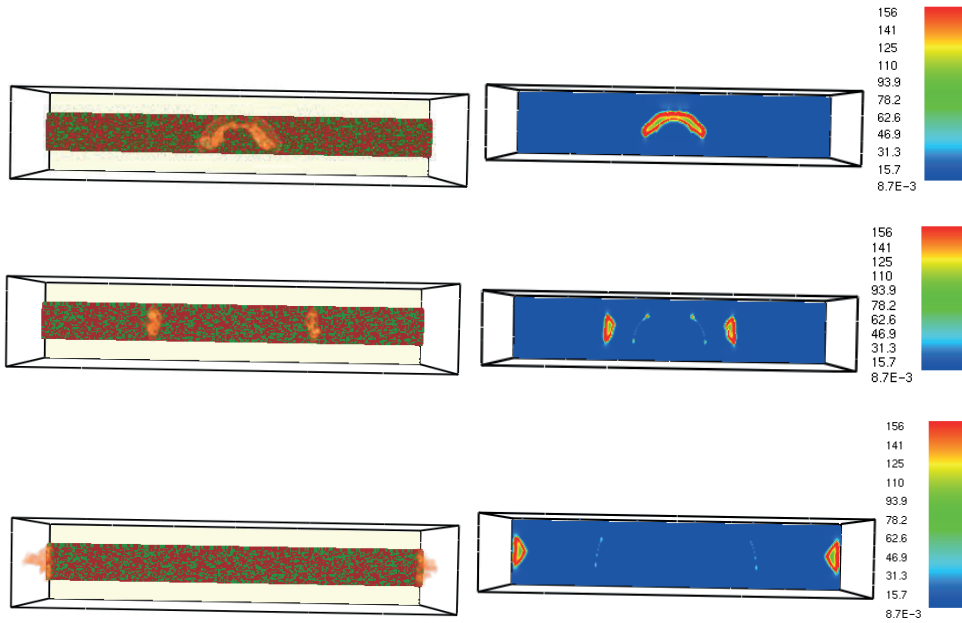


Figure 9: HRRPUV and heat flux ( $\text{kW/m}^2$ ) in the fourth case (top: 177 s, middle: 350 s, bottom: 739 s)

Source: Compiled by the authors.

It can be seen that the fire spreads faster and the intensity of the fire is also greater. Accordingly, the fire plume is wider. The maximum value of the heat flux is also higher.

The fire spread and heat flux in the fifth case is shown in Figure 10.

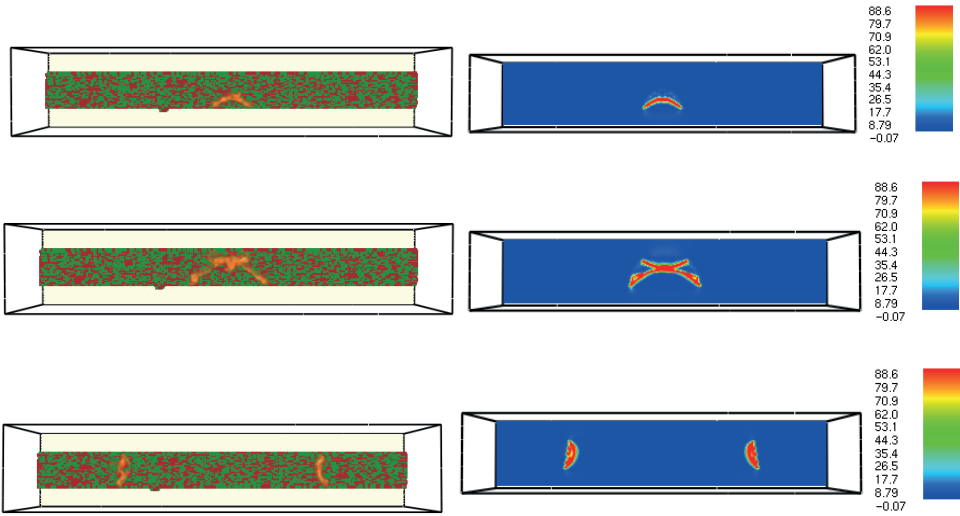


Figure 10: HRRPUV and heat flux ( $\text{kW/m}^2$ ) in the fifth case (top: 200 s, middle: 350 s, bottom: 900 s)

Source: Compiled by the authors.

It can be seen that the spread of the fire is similar to the first case. The maximum value of the heat flux is also similar. However, the shape of the fire plume changed on the side where the trees are. This change can also be observed in the heat flux.

The ROS is shown in Table 2.

Table 2: ROS (rate of spread) (m/s)

	Before splitting in y direction	Before splitting in x direction	After splitting in x direction
Case 1	0.039	0.042	0.05
Case 2	0.043	0.093	0.053
Case 3	0.049	0.042	0.052
Case 4	0.08	0.075	0.11
Case 5	0.04	0.04	0.053

Source: Compiled by the authors.

It can be seen that compared to the original setting, ROS increased in all cases. It can be seen that the ROS in the x direction increased significantly when there was wind or when the vegetation was dry. Trees and low vegetation only minimally increased ROS.

The heat release rate (HRR) curves are shown in the following figure.

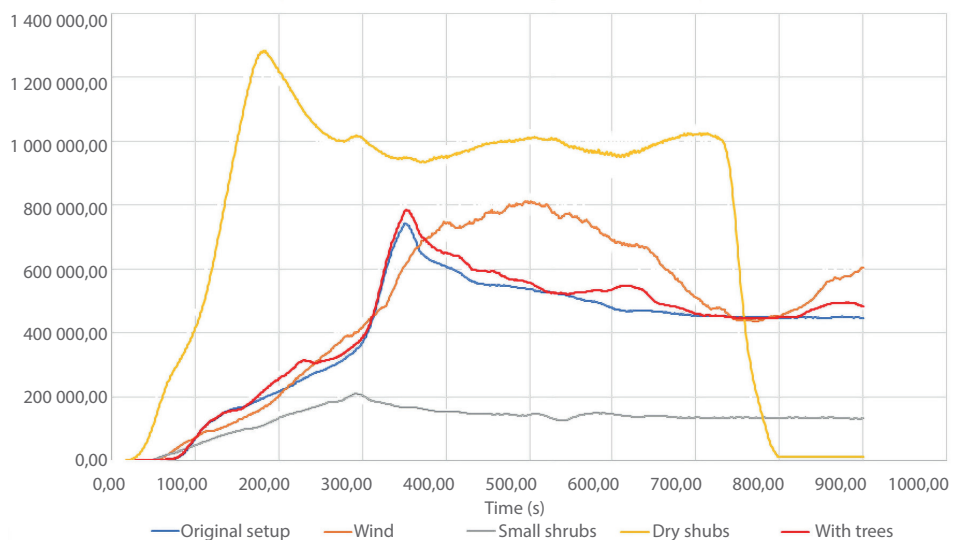


Figure 11: Heat release rate

Source: Compiled by the authors.

At the original settings, the HRR curve first increases almost linearly, then when it reaches the other side it rises rapidly, after that it starts to decrease and finally settles to a constant. The HRR curve developed similarly when there were a few trees in the field. The HRR curve differs in that its maximum is higher and when the fire reaches a tree, there is a jump in the curve. In case of low shrubs, the curve rises more slowly. It reaches its maximum at about 280 s, then decreases, and then becomes constant. In case of wind, the curve first increases linearly. It rises faster at about 310 s till about 400 s, at which point the rise decreases. It reaches its maximum at 500 s, then starts to decrease. It reaches a local minimum at about 750 s, after which it starts to increase again. This can be explained by the fact that the fire started to spread on the other side as well. In case of dry shrubs, the HRR increases rapidly, reaches a maximum at 160 s, starts to decrease, then becomes constant, and finally drops to 0 at 800 s, when the fire front reaches the edge of the field.

The intensity of the fire can be calculated using the following formula<sup>23</sup>.

$$I \approx \frac{HRR_{avg}}{w}$$

where  $I$  is the average value of the HRR, when the fire is fully developed, and  $w$  is the width of the field. The intensity of the fire is shown in the following table.

<sup>23</sup> Frangieh et al. (2018): op. cit



Table 3: Intensity of fire

	Case 1	Case 2	Case 3	Case 4	Case 5
HRR <sub>avg</sub> (kW)	392582.34	471874.82	128682.39	741782.70	414929.03
I (kW/m)	2617.22	3145.83	857.88	4945.22	2766.19

Source: Compiled by the authors.

It can be seen that compared to the original setting, the intensity of the fire increased a little when there were trees in the field. The intensity of the fire also increased when there was wind. The intensity of the fire increased significantly in case of dry vegetation but decreased significantly in case of low shrubs.

## Conclusion

In the course of our research work, a simulation model was created and ran related to the spread of fire in a shrubby area (vegetation) with the parameters we determined. We presented the applied simulation model, and also examined how the size of the non-combustible area affects the simulation results. It was found that considering a non-burnable area corresponding to half of the shrubby area led to a suitable result in terms of calculation time and accuracy as well. After that, 5 different settings were examined. It was found that the dryness of the shrubs and the wind significantly increase the spread of the fire. In case of low shrubs, the speed of fire spread increased, but at the same time, its intensity decreased. When there were a few trees in the terrain, it increased the intensity of the fire minimally. The aim of the research is to investigate vegetation fires in a simulation environment, for which detailed knowledge and testing of the applied WFDS program is essential. According to our experience, the WFDS program can also be suitable for investigating fires in forests and vegetation with variable settings, which we intend to carry out in the future.

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# Developing Space Programs and Cooperation in Latin America<sup>1</sup>

Andr as EDL<sup>2</sup> 

*A few countries in Latin America, like Mexico, Argentina, Brazil have already achieved notable results in their own space programs even before the current wave of space activities. Smaller countries in the region, due to possible commercial gains, scientific achievements and security concerns also turned their attention towards space. The chance for cooperation with major space actors, like the United States, the European Space Agency (owning a significant base in French Guiana), or the People’s Republic of China is a tempting offer, but not without its own pitfalls. To strengthen their position and their own space programs 18 nations recently founded the Latin American and Caribbean Space Agency (Agencia Latinoamericana y Caribe a del Espacio). In this paper we shall examine the recent developments in the region’s space activity and the influence of major space powers, especially that of China and the U.S.*

**Keywords:** Latin America, space, ALCE, Argentina, Brazil

## Introduction

In recent years, the interest has increased in countries and regions which are latecomers in the space domain. They could provide new markets and be valuable partners for cooperation. Latin America even with its turbulent history and many unsolved problems offers a wide range of possibilities for domestic and foreign space endeavours. Earth observation is a key component for border supervision, environmental protection, agriculture, resource extraction, disaster control, urban planning and many other fields. Communication, including fast broadband internet, is also a boost or some say more and more a necessity for development. Latin America’s size and geographical location make the countries in the region a great candidate for the establishment of satellite ground stations or observatories. The closeness of the equator is beneficial for building launch facilities to decrease launch costs for certain projects. At the same time Latin America’s space sector – despite the opportunities and results until this point – is still in its infancy and has to cope with the

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problems of furthering domestic growth without alienating foreign capital investment and turning down offers for joint projects and still foster cooperation between Latin American countries.

The literature about the region's space sector is scarce, but growing in recent years. Gocłowska-Bolek gave an overview of the region's interest in space, showed the role of space in innovation and focused on Brazil's new era in space research. Brazil being a key space player in the region has drawn more attention to itself as early as the 2010s. Harvey and colleagues dedicated a chapter to Brazil in their book about emerging space powers. Other sources tend to analyse the subject in light of cooperation with major space powers. With the changing status quo especially prominent is the role of China and its competition with the United States. Klinger and many reports from Western think tanks and institutions examine this important aspect. Two books published in 2020 edited by Froehlich and colleagues cover a wide range of subjects from national space programs, space sustainability, transformative technology, education or even cultural heritage.

With analysing Latin America's current space activity we can discover a lot of potential for growth and cooperation with European actors. Also, examining the different trends and processes can highlight opportunities and provide valuable lessons for smaller, relatively new space-faring countries. The aim of this paper is to introduce some of the developments between 2020 and 2022, shed some light on the China–U.S. competition, give a more detailed description of the Argentinian space program and the lessons provided by it, and examine the establishment of the Latin American and Caribbean Space Agency (Agencia Latinoamericana y Caribe a del Espacio – ALCE) and its possible implications. The paper will first introduce the state of Latin America's space activity in the 21<sup>st</sup> century, especially the satellite sector, and give one example of a successful space company. Later we examine the influence of major space powers, and finally, take a look at an attempt for cooperation in the region.

## The start of Latin American space programs

The start of Latin America's space activity goes back to the era of the Cold War. The most capable actors in the region were Brazil and Argentina, both were launching rockets relatively early, Argentina in 1961 (Alfa-Centauro rocket) and Brazil in 1967 (Sonda-I rocket). Ever since that they have had a significant missile development project and operated launch sites, and both established national space agencies in the 1990s.<sup>3</sup>

Brazil was under the rule of military governance between 1964 and 1984, therefore, there was a great emphasis on rocket development. Besides the testing rockets, a milestone achievement was to start the China–Brazil Earth Resources Satellite (CBRES) program in 1988.<sup>4</sup>

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<sup>3</sup> Bruno Victorino Sarli et al.: Review of Space Activities in South America. *Journal of Aeronautical History*, 8 (2018). 208–232.

<sup>4</sup> Brian Harvey et al.: *Emerging Space Powers. The New Space Programs of Asia, the Middle East, and South America*. Chichester, Praxis Publishing, 2010.

Argentina in competition with Brazil benefited considerably from German scientists arriving into Argentina after the second world war. The space program had close ties with the military and allegedly even helped Iraq with their rocket program, but this was later suspended.<sup>5</sup> A lesser-known fact is that Argentina launched the 4<sup>th</sup> animal, a rat named Belisario into space in 1967.<sup>6</sup>

The first astronaut from the region was the Cuban pilot Arnaldo Tamayo Mendez, on the board of Soyuz 38 launched on the 18<sup>th</sup> of September 1980. This mission was a part of the Interkosmos program, so Cuba could achieve this goal with the aid of the Soviet Union.<sup>7</sup>

### ***The new space age for Latin America***

The beginning of the second phase of space exploration was more like a period instead of an exact point in time. The fall of the Soviet Union, not only changed the geopolitical landscape but also human activity in space, which is strongly dependent on circumstances on Earth. The First Gulf War signalled an important transition regarding space as well, because for the first time in history a military force relied heavily on space capabilities. This transition into the new space age also got a new momentum in the 2000s due to new technologies and emerging rivalries between great space powers.

Latin American nations also saw this new trend and they quickly realised even smaller nations can benefit from space. They also realised, in case they are not seizing the opportunity they will be easily excluded from this new segment and rely on foreign entities to provide even the most essential space-based services.

It is important to note that countries in the region are part of the international space community. One of the most important organisations is *The Committee on the Peaceful Uses of Outer Space* (COPUOS) which was set up by the United Nations General Assembly in 1959. Argentina and Brazil were among the founding members. By 2021, the majority of countries in the region (17 out of 33)<sup>8</sup> became member states of COPUOS.<sup>9</sup> The Committee played a crucial role in creating five treaties which are still fundamental in space law. These are the Outer Space Treaty, the Rescue Agreement, the Liability Convention, the Registration Convention and the Moon Agreement. However, among Latin American countries there is great variability in how they regard these treaties. As of 1 January 2022, the Moon Agreement is only signed and ratified by eighteen countries in the world. Among them we can find Chile, Mexico, Peru, Uruguay and Venezuela. The remaining four treaties have a higher ratification rate in the region but are still not universally accepted.<sup>10</sup>

<sup>5</sup> Sarli et al. (2018): op. cit.

<sup>6</sup> Marina Aizen: Belisario, el rat n que fue astronauta. *Clar n*, 16 April 2017.

<sup>7</sup> Spacefacts: Soyuz 38. *Space Facts*, 02 September 2021.

<sup>8</sup> Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, the Dominican Republic, Ecuador, El Salvador, Mexico, Nicaragua, Panama, Paraguay, Peru, Uruguay, Venezuela.

<sup>9</sup> Secretariat of COPUOS: Committee on the Peaceful Uses of Outer Space: Membership Evolution. *UNOOSA*, s. a.

<sup>10</sup> COPUOS Legal Subcommittee: Status and applications of the five United Nations treaties on outer space. *COPUOS*, 28 March 2022.

## ***An overview of current Latin American space activities***

Argentina in the 2000s and 2010s continued its space program, deploying ARSAT satellites to GEO orbits, and establishing CONAE, the national space agency. Political and economic problems somewhat hindered the progress of the state-funded space program but there was a significant change due to the involvement of the private sector, as we will cover in a later subsection. Regardless of this, Argentina is one of the few countries in the region developing its own launch capabilities, like the Tronador rocket family.<sup>11</sup>

Brazil invests diligently in its own space program. In 1994, Brazil established the Brazilian Space Agency (*Ag ncia Espacial Brasileira – AEB*) which is under civilian authority, in contrast to the strong military supervision of the earlier decades. The two main launch facilities are Alc ntara Launch Center (*Centro de Lan amento de Alc ntara – CLA*) and Barreira do Inferno. The former launch centre was the site of an unfortunate accident in 2003, when a VLS-1 type rocket exploded on the launch pad resulting in numerous deaths and considerable damage to the facility. The following investigation revealed many problems due to lack of funding and mismanagement. Despite this huge setback in 2004, Brazil managed to send its first missile into space, the VSB-3. In 2007 – executed jointly with Argentina – the second missile launch was also successful.<sup>12</sup> In the coming years Brazil completed important milestones. They sent an astronaut to ISS in 2006. In 2021, Brazil also joined the U.S. lead Artemis accord.<sup>13</sup> And as many countries in the region they intend to encourage foreign investment. As an early example, they started cooperation with Russia and Ukraine, to develop rockets. The Ukrainian Cyclone-4 rocket was promising, as was the Southern Cross rocket family based on the Angara rockets.<sup>14</sup> The high-level Russo–Brazilian cooperation did not stop by space rockets but provided many results in the area of nuclear, cyber and aviation systems.<sup>15</sup> Another such move was to sign the Technological Safeguard Agreement in 2019 and thus enable four companies to use Alc ntara for launching their payload.<sup>16</sup> Between 2019 and 2022, partly due to the war in Ukraine, the two countries cooperated mainly through the BRICS group, one example being the cooperative satellite network initiated by China.<sup>17</sup>

Peru launched its first space probe in 2006, and shortly the first satellite followed in 2014 as a result of a university project, which is not unusual for a new entity in the space sector. They also engaged in a project with Kursk University from Russia, and it could be noted that an arms deal contract was signed with Russia in the 2010s.<sup>18</sup> Peru is also

<sup>11</sup> Annette Froehlich et al.: *Space Supporting Latin America. Latin America’s Emerging Space Middle Powers*. Cham, Springer, 2020. 146–184.

<sup>12</sup> Joanna Gocłowska-Bolek: Latin American Space Research – Challenges and Opportunities. *Transactions of the Institute of Aviation*, 4, no. 249 (2017). 24–34.

<sup>13</sup> NASA: Brazil Signs Artemis Accords. *NASA*, 15 June 2021.

<sup>14</sup> Gocłowska-Bolek (2017): op. cit.

<sup>15</sup> Imanuela Ionescu: Brazil–Russia Military-Technical Cooperation. *Military Review*, December 2018.

<sup>16</sup> Shelli Brunswick: Op-ed. Order and Progress – Brazil’s Second Act in Space. *Spacenews*, 17 March 2022.

<sup>17</sup> Juan Pons: China Speeds up the Activation of a Cooperative Satellite Network with Russia, India, Brazil and South Africa. *Atalayar*, 06 June 2022.

<sup>18</sup> Gocłowska-Bolek (2017): op. cit.

involved in research connected to Mars, through the Mars Society, helping to simulate Mars Exploration Crew missions.

Bolivia, one of the poorest countries in the region, has also launched its first satellite in 2013 but only with the help of Chinese financial and technological assistance.

Venezuela also received significant assistance from China in its own space program, thus managed to build two satellites, Venesat-1 in 2008, which is a communication satellite, and VRSS-1, a remote sensing satellite in 2012. The exchange student program is also quite significant between the two countries.<sup>19</sup>

Mexico started a satellite program in the 2000s, and in 2009 launched SatMex, a company bought in 2014 by Eutelmex, a European company. Ever since the acquisition, Mexico and Eutelmex are conducting joint research programs to further develop satellites. Budgetary problems are constant for the Mexican Space Agency (founded in 2011) but they are dedicated to implement space strategies and enhance cooperation with foreign entities.<sup>20</sup>

Chile was one of the countries with the earliest space facilities. In 1957, they already had two locations for NASA. One was later closed, the other one was sold to a Swedish company in 2009. In 1998 they could launch their first satellite. They are mostly interested in earth observation and communication.<sup>21</sup>

Although the Bogota Declaration<sup>22</sup> in 1976 is connected to Colombia, the country can also be considered a latecomer and started a more serious space endeavour in 2007. The main goal is to set up a strong foundation for a space industry in the area of Medell n. However, there is an ongoing debate among Colombian decision-makers if they should buy images or deploy their own imaging capability in space.<sup>23</sup>

## **Satellites**

According to the Satellite Database of the Union of Concerned Scientists as of 1 January 2022, the number of satellites operated by Latin American countries were the following:

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<sup>19</sup> Sarli et al. (2018): op. cit.

<sup>20</sup> Froehlich et al. (2020): op. cit. 334–398.

<sup>21</sup> Froehlich et al. (2020): op. cit. 276–303.

<sup>22</sup> Also known as the Declaration of the First Meeting of Equatorial Countries, made and signed by seven countries. They attempted to assert sovereignty over parts of the geostationary orbit which are constantly over their nations' territory.

<sup>23</sup> Sarli et al. (2018): op. cit.

Table 1: Number of Latin American Satellites (as of 1 January 2022)

Argentina	30
Bolivia	1
Brazil	13
Chile	1
Colombia	1
Ecuador	1
Mexico	7
Paraguay	1
Peru	1
Venezuela	2
China/Brazil	2
USA/Japan/Brazil	1
USA/Argentina	4
<b>Total</b>	<b>65</b>

Source: Compiled by the author based on Union of Concerned Scientists (2022): op. cit.

As we can see based on this table Argentina is in the lead and we will cover the reasons shortly. Second is Brazil, third is Mexico, and the remaining countries had 1 or 2 active satellites. It is interesting to see that 7 satellites are operated jointly with other nations. The two biggest space powers in the region are Argentina and Brazil; therefore, there is not much of a surprise that they are the ones involved in these projects.

After adding the number of the 11 satellites (10 for Argentina, 1 for Brazil) which have been launched since the 1<sup>st</sup> of January 2022, we come to a result of 76 satellites in orbit. We can also take a look on the distribution of main operators and the purpose of Latin American satellites.

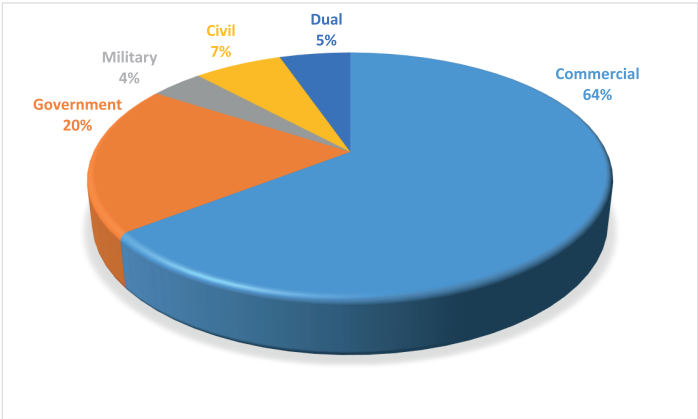


Figure 1: Latin American satellite operators by sector (as of 28 May 2022)

Source: Compiled by the author based on Union of Concerned Scientists (2022): op. cit.; Gunter’s Space Page (2022a): op. cit.



It is clearly visible that the commercial sector is dominant, so the region's distribution by sectors seems to follow recent international trends. There is a significant shift towards the commercial applications of space, but in Latin America there is no sign of build-up in the military domain, which can be observed by major space powers. It is also worth to add that this overweight of the commercial sector is mainly due to Argentina, and two of its projects. Before introducing these projects we must take a look at the purpose of active satellites.

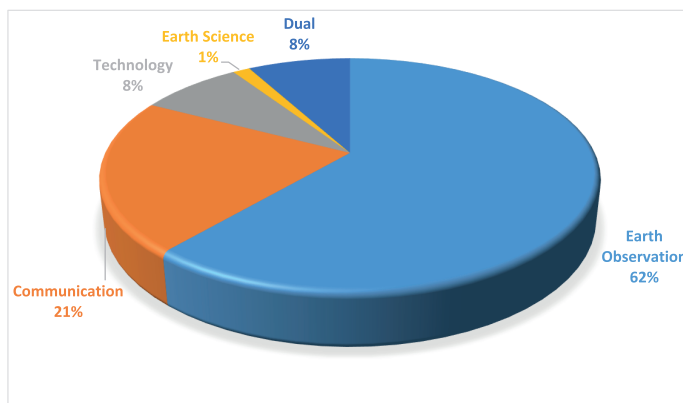


Figure 2: Purpose of Latin American satellites (as of 28 May 2022)

Source: Compiled by the author based on Union of Concerned Scientists (2022): *op. cit.*; Gunter's Space Page (2022a): *op. cit.*

### ***The example of a successful startup – Satellogic***

One of the most ambitious and interesting project is the Aleph-1 constellation. The constellation is still in the deployment phase, according to plans the constellation will have 90 satellites. It was built by Satellogic S. A. a company founded in 2010, and now with multiple offices around the world, their HQ is in Montevideo, Uruguay.<sup>24</sup> The structure of the company is vertical, meaning they design and build their own satellites, but also provide next-level services based on these capacities like imagery and data analysis. Satellogic also started to trade its shares on the American stock market Nasdaq, to acquire more capital. The initial entry into the market was favourable, how they will perform later on is yet to be seen.<sup>25</sup>

The company owns a significant portion of Argentinian satellites. According to the UCS database 21 out of 30 satellites belonged to Satellogic.<sup>26</sup> In the first half of 2022, the company launched an additional 9 satellites, 5 on the 1<sup>st</sup> of April 2022, and the rest on the 25<sup>th</sup> of May 2022, thus Aleph-1 reaching 31 satellites in orbit and the number

<sup>24</sup> Satellogic (<https://satellogic.com/company/contact-us/>).

<sup>25</sup> Marketwatch ([www.marketwatch.com/investing/stock/sat](http://www.marketwatch.com/investing/stock/sat)).

<sup>26</sup> Union of Concerned Scientist (2022): *op. cit.*

of Argentinian satellites has risen to 39.<sup>27</sup> This follows international trends, because the significant increase in satellites are usually due to constellation deployments, like OneWeb, Starlink and other constellations soon to follow. The recent launches were conducted by SpaceX Falcon-9 rockets, but previously Chinese Long March rockets and even a European Vega rocket were used, adapting to lower prices and available launch windows. The satellite type is  NuSat, developed and built by Satellogic after they gathered enough expertise during the BugSat and CubeBug programs.  NuSats are identical earth observation satellites, with 37.5 kg in mass and imaging systems operating in the visible and the infrared spectrum. The aim is to provide commercially available real-time Earth imaging and video for customers, with a ground resolution of 1 meter.<sup>28</sup>

Satellogic is a great example for a latecomer company that could find a small niche in an already well-developed space sector. This is the viable route for most startups and countries joining in the second space age. Using already developed and reliable capabilities (like rockets of different companies) makes sense instead of engaging in a costly and long development program of their own.

## China, the U.S. and other major space actors in the region

As mentioned previously, relatively latecomer companies and countries can build their own strategy on already existing capabilities. But a considerable strategic disadvantage is that at the same time they are dependent on these first-line service providers. Disruptions in the supply chains, political turmoil, conflicts, natural disasters, or business competitors can severely limit or even halt space activity for countries and companies.

One strategy might be to choose between multiple offers and pick the best provider based on financial or political reasons. But major space powers try to gain an advantage in the region and try to convince local entities to pick their services. However, when they cannot offer their own capacities, they might try to stop picking the main rival's offer, and favour more neutral choices. Therefore, local governments and companies can choose between Chinese, American, European, or other actors with a launch capacity and try to maintain some kind of balance and freedom of decision. Yet this still does not fully solve the problem of lacking their own launch capacity, and without that true space autonomy is not possible. Brazil and Argentina have their own rocket development program with considerably good results, yet they could also benefit from pooling resources and cooperation with other countries in the region. This can also aid the integration of the continent, boost the economy and a backup plan can give them a better position when negotiating with foreign entities.

The presence of major powers in Latin America is a problematic phenomenon. The FDI, technological know-how or even the chance to take part in different projects is valuable for countries in the region. On the other hand, there is a danger of getting too much under the influence of any foreign entity. The problem of how to strengthen their

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<sup>27</sup> Gunther's Space Page (2022a): op. cit.

<sup>28</sup> Gunther's Space Page:  NuSat 1. *Space.skyrocket*, 26 May 2022b.

positions without needlessly antagonising any major powers or potential partners is a core problem of international relations.

Traditionally, Latin America was considered a region of high interest for the United States. While the U.S. pays more and more attention to the Pacific region, a prominent review commission came to the conclusion that they neglected this important area, and therefore China managed to gain a significant foothold.<sup>29</sup> European powers or Russia are also present in the region, but their weight cannot be compared to the U.S. and China. In recent years Beijing granted numerous loans to governments and state-owned enterprises through China’s policy banks (China Development Bank – CDB, and China ExIm Bank), mainly in the 2010s. Clearly, the focus was on the energy sector, but infrastructural developments, mining and other small scale programs were also significant.

The following graph shows only the biggest beneficiaries of the Chinese loan programs, with amounts received over 1 billion USD. But at least 12 more countries got some kind of loans from Beijing, and this excludes the amounts received from commercial banks (Bank of China, China Construction Banks, etc.). The 5 biggest borrowers are Venezuela (62.5 billion USD), Brazil (30.5 billion USD), Ecuador (18.2 billion USD), Argentina (17 billion USD) and Bolivia (3.2 billion USD).<sup>30</sup>

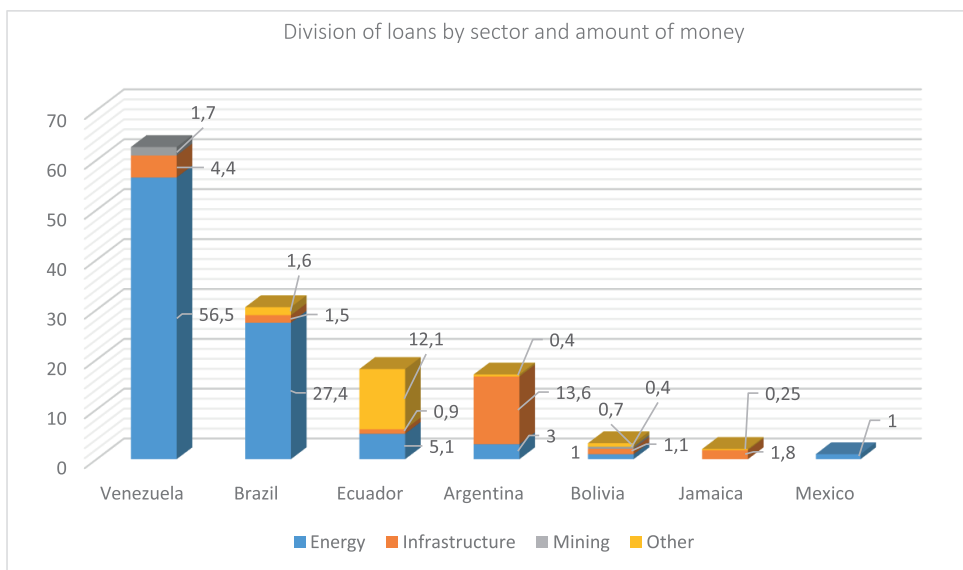


Figure 3: Latin American countries with over 1 billion USD loans from China

Source: Gallagher–Myers (2022): *op. cit.*

The U.S. did notice the increase in Chinese investments and the growing influence of China. A 2022 Congress report estimated that apart from these loans, between 2005 and

<sup>29</sup> U.S.–China Economic and Security Review Commission: 2021 Annual Report to Congress: China’s Influence in Latin America and the Caribbean. *USCC*, 20 May 2021.

<sup>30</sup> Kevin P. Gallagher – Margaret Myers: China-Latin America Finance Database. *The Dialogue*, 20 May 2022.

2021 China invested 140 billion USD in the region. Brazil accounted for 64 billion and Peru 25 billion USD. 59% of the investment went to the energy sector, but 24% to metals/mining. The shift towards mining in the investment area compared to loans is noticeable.<sup>31</sup>

The biggest borrowers (see Figure 3) all received significant help in their national space programs, as well. According to a report issued by the U.S.–China Economic and Security Review Commission until 2021 China helped to develop and launch at least 21 satellites: 10 for Argentina, 6 for Brazil, 3 for Venezuela, 1 for Bolivia and 1 for Ecuador. Bolivia’s satellite was financed with a loan from one of the above-mentioned policy banks, the China Development Bank.<sup>32</sup> China’s involvement in the region including space cooperation – even though alarmist voices from the U.S. might say otherwise – is not a recent occurrence, it has a decade-old history and is based on the ideology of the South–South cooperation, in order to achieve more independence from the North. One of the earliest examples for this is the successful China–Brazil joint earth observation program to develop the China–Brazil Earth Resources Satellite (CBERS) network. This program already started in the 1980s and was a notable step towards data independency. The Asia-Pacific Space Cooperation Organization (APSCO) also have members like Pakistan or Iran, not just Latin American countries and China. The autonomy of the South is also represented in the documents. In 2015, the organisation issued a statement which recognised that China’s Belt and Road Initiative is in alignment with APSCO’s goals.<sup>33</sup> Currently, the only Latin American member is Peru, but other countries send observers and are interested in cooperation.<sup>34</sup> This might increase as soon as the planned data service platform and the Joint Small Multi-mission Satellite Constellation becomes functional. China reaffirmed its dedication towards the programs and further cooperate with countries in the region.<sup>35</sup>

Besides the possible benefits, there are some concerns as well. The Commander of the U.S. Southern Command, Admiral Craig S. Faller gave a speech about U.S.–China strategic competition in the Western Hemisphere. According to him, China uses the loans and other kinds of connections to convert these assets to hard power and sometimes even coerce its partners into deals, which they could not refuse due to economic dependencies.<sup>36</sup> The issues about the Chinese satellite tracking station close to Neuqu en in Argentina raised concerns not just among U.S. analysts, who claimed that the station is used to spy on American satellites. But the opposition also had some questions about the deal with China which does not seem all that beneficiary to Argentina. The station is in operation since 2018, China does not have to pay taxes or rent for the 50 years of using the area. Argentina in return got 10% of the antenna’s operation time. The station is operated by the China Launching and Satellite Control General (CLTC) which is under the command of

<sup>31</sup> Congressional Research Service: China’s Engagement with Latin America and the Caribbean. *Sgp*, 4 May 2022.

<sup>32</sup> U.S.–China Economic and Security Review Commission (2021): op. cit.

<sup>33</sup> Julia Michelle Klinger: A Brief History of Outer Space Cooperation Between Latin America and China. *Journal of Latin American Geography*, 17, no. 2 (2018). 46–83.

<sup>34</sup> Asia-Pacific Space Cooperation Organization: Member States. *Apsco*, 20 February 2019.

<sup>35</sup> China National Space Administration: China’s Space Program: A 2021 Perspective. *CNSA*, 28 January 2022.

<sup>36</sup> Project 2049 Institute: Near and Present Danger: SOUTHCOM Commander ADM Faller on U.S.–China Strategic Competition in the Western Hemisphere. *Project2049*, 15 June 2021.

the People’s Liberation Army. The government claims that there are no secret activities going on, the contract does not have secret appendixes and emphasises the benefit for the region.<sup>37</sup> Sceptics on the other hand point out the dubious wording of some of the articles in the contract and are worried about the lack of oversight, and the violation of Argentinian sovereignty. Considering that space technology is dual-use in most cases, identifying the nature of the activity is uncertain without control.<sup>38</sup> Some Argentinian analysts think it is *de facto* a military base.<sup>39</sup> In 2021, the government announced that in Rio Gallegos, a town close to the South pole, a Chinese–Argentinian joint venture will build a satellite ground station. The Chinese firm, Beijing Aerospace Yuxing Technology Co. Ltd. (Satelliteherd) has partners affiliated with the Chinese military.<sup>40</sup> Many are worried that economic problems, the effect of Covid and other factors might give a chance to China to further gain influence in Latin America. The U.S. Congress proclaimed that they will counter Chinese efforts in Latin America in multiple areas.<sup>41</sup> In addition, a change of strategies and attitudes might be in order, because China has a much more pragmatic approach tailored to every country in the region, while the U.S. seems to focus on warnings about long-term consequences and a top-down approach.<sup>42</sup> The response has to be swift because China increased its share in trade in Latin America and 20 countries already joined the Belt and Road initiative. Most of them also recognised the PRC’s claim on Taiwan. Apart from Neuqu n, China has satellite ground stations in Bolivia, Brazil, Ecuador and Venezuela.<sup>43</sup>

Besides the U.S. and China, Russia, the EU and Japan are also interested in space cooperation. The European Space Agency (ESA) has a satellite tracking station in Argentina, close to Malag en. The facility is quite sophisticated and is a key component in ESA’s global tracking network. However, the conditions are very different, because ESA is a strictly non-military organisation, unlike CLTC. Therefore, the station never raised such concerns, not even among the Argentinian opposition. The European presence in the region is further enhanced by the Guiana Space Center near Kourou, a sophisticated base with launch pads for Ariane and Soyuz rockets and a tracking station.<sup>44</sup>

As mentioned previously, Russia and Ukraine were also active in the region, and previously launched payloads for Latin American countries and engaged in joint research programs. Russia had a contingent of scientists and technicians in the European space launch centre in Kourou, because ESA and other actors used Soyuz rockets to launch payloads from this location. In February 2022, Moscow announced that it will withdraw this personnel as a response to European sanctions implemented against Russia for

<sup>37</sup> Olivia Sohr: Cinco puntos para entender la estaci n espacial china en Neuqu n. *Chequeado*, 10 February 2015.

<sup>38</sup> Zyri: Chinese Space Base in Neuqu n: What Uses Did Argentina Give It in the Last Decade. *Zyri*, 27 March 2022.

<sup>39</sup> Ignacio Conese: How China Solidified Its Foothold in Latin America through a Space Centre. *TRTWorld*, 17 March 2020.

<sup>40</sup> ANI: China Space Contractor to Install New Satellite Ground Station in Southern Argentina: Report. *ANI News*, 29 May 2021.

<sup>41</sup> Congressional Research Service (2022): op. cit.

<sup>42</sup> Thiago de Aragao: The US Still Doesn’t Understand China’s Strategy in Latin America. *The Diplomat*, 08 September 2021.

<sup>43</sup> Diana Roy: China’s Growing Influence in Latin America. *Council on Foreign Relations*, 12 April 2022.

<sup>44</sup> The European Space Agency: Launch site. *ESA*, 20 May 2021.

attacking Ukraine.<sup>45</sup> To what degree and when these two countries might be returning to play an active role in Latin America's space activity is yet to be seen.

## The joint Latin American initiative

The idea of Latin American cooperation in space activities is not a new one. The region had different organisations set up previously to strengthen ties between the countries. One of them was UNASUR (*Uni n de Naciones Suramericanas*). The organisation was established in 2008, but as it seems the initiative failed by the end of the 2010s and only 4 members remained in the organisation.<sup>46</sup> In 2011, however, when prospects seemed more optimistic, they proposed the establishment of a South American Space Agency. This was in the interest of many countries, especially for financial reasons, including regional powers like Argentina and Brazil, the later especially keen on cooperation after the bankruptcy of the Brazilian defence industry in the 1990s.<sup>47</sup>

There is also some rivalry in the background, due to public image and the competition to attract projects and investment to one's country. The two most capable countries Brazil and Argentina engage in this kind of competition, but also can work together on programs like nuclear reactor development.<sup>48</sup> Potentially, these could be used as a future energy source for space vehicles. Personal and ideological conflicts also influence the outcome of projects. Brazilian President Jair Bolsonaro and Alberto Fern andez the President of Argentina are known to exchange regular insults, so cooperation is rather difficult.<sup>49</sup>

The tensions between Brazil and other nations in the region added significantly to the decision of Mexico and Argentina that they will spearhead the creation of Latin American and Caribbean Space Agency (*Agencia Latinoamericana y Caribe a del Espacio – ALCE*). In September 2021, seven countries signed the agreement to establish the agency.<sup>50</sup> The proposed model the agreement wishes to implement is similar to that of ESA. National space programs would still continue but in addition member states would have joint projects.<sup>51</sup> The number of members soon grew to nineteen and more countries are expected to join. Brazil, Columbia and Chile are not among them, but Cuba is.<sup>52</sup> If the region cannot get over ideological and personal differences, the initiative might fail just like UNASUR. The HQ of the agency is in Mexico. The declared goals are capacity sharing, the design

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<sup>45</sup> Jeff Foust: Russia Halts Soyuz Launches from French Guiana. *Spacenews*, 26 February 2022.

<sup>46</sup> In 2018 six countries suspended their membership. Later Colombia, Brazil, Ecuador, Argentina and Uruguay even announced that they would withdraw from UNASUR, and some of them joined PROSUR (*Foro para el Progreso e integraci n de Am rica del Sur*).

<sup>47</sup> Go łowska-Bolek (2017): op. cit.

<sup>48</sup> Go łowska-Bolek (2017): op. cit.

<sup>49</sup> DW: Alberto Fern andez pide a Bolonaro dejar sus „diferencias” e impulsar Mercosur. *Deutsche Welle*, 31 November 2020.

<sup>50</sup> Argentina, Mexico, Bolivia, Ecuador, Paraguay, Honduras and Costa Rica.

<sup>51</sup> Christian Santana: El despegue de el Agencia Latinoamericana del Espacio. *Universidad de Navarra*, 17 January 2022.

<sup>52</sup> Government of Mexico: M xico ser  sede de la Agencia Latinoamericana y Caribe a del Espacio. *Gobierno de M xico*, 16 March 2022.

and launch of a nanosatellite, and increasing independence from foreign space powers.<sup>53</sup> This need for independent space capacities is felt throughout the region. For example, in November 2020 Mexico had to ask for the help of the EU to evaluate the damages caused by Hurricane Eta in the southeastern part of the country. The Copernicus Emergency Management Service (CEMS) could carry out this task, and provide information that only geospatial information can provide.<sup>54</sup>

Another problem will be the financing of the agency. The original budget for ALCE was around 100 million USD, very small compared to the budget of NASA or ESA.<sup>55</sup> Countries like Brazil, Argentina or Peru could afford the minimum estimate of 5.5 million USD per year for operational costs, but smaller countries might relocate funding, or wait for the end of the election cycle.<sup>56</sup> This is the same problem that U.S. officials are facing in the region when they are trying to argue against involvement with the Chinese, reminding decision-makers on long-term effects. Short term benefits often overrule the longer strategic perspectives. Besides the budget and time perspective problem, there is also the problem of differences between member states in the technological and infrastructural backgrounds. It will be highly difficult to coordinate research when even the most basic elements are missing in some countries. Ecuador even shot down its own space agency in 2018 as a part of economic austerity measures. The involvement of the private sector could be key to solve this problem.<sup>57</sup> In return, the private sector can benefit a lot from institutional support. One example for this is Dereum Labs. The Mexican start-up company could sign a contract with Airbus in 2021 about jointly taking part in resource exploration on the Moon. The support of Mexico's space agency (AEM) was crucial for the deal because through the agency Dereum Labs has access to research facilities and other projects.<sup>58</sup>

## Conclusion

As established in the current paper, Latin America has a lot of potential in the space domain. The interest of major space powers and the business community is understandable due to the region's resources, population, need for development and strategic importance. Countries in Latin America – just like any other aspiring and new space-faring nation – must carefully balance the benefits and drawbacks of foreign investment, especially the role of China. They also must find ways to enhance cooperation between each other, and support local startups and initiatives with financial and legal means while providing the necessary infrastructure and connections to increase competitiveness in the global space markets. According to most experts, budgetary restraints and political division will

<sup>53</sup> Myriam Vidal Valero: Latin America's Moonshot. *Slate*, 06 May 2021.

<sup>54</sup> Delegation of the European Union to Mexico: La Uni n Europea apoya a M xico a enfrentar las inundaciones em el sureste con mapeo. *EEAS Europa*, 18 November 2020.

<sup>55</sup> Santana (2022): op. cit.

<sup>56</sup> Juan Pablo Espinosa: A New Kid on the Block: ALCE – Latin America's Space Agency. *GU Space Initiative*, 13 January 2021.

<sup>57</sup> Vidal Valero (2021): op. cit.

<sup>58</sup> Ana Campoy: Why Latin America Needs Its Own Space Agency. *Quartz*, 20 January 2022.



be a prevalent problem in the near future. Harmonising cooperation between different political-ideological blocks and highly varying development levels is also a challenge. The establishment of ALCE or the chance for commercial entities to reach across borders could be a possible solution if decision makers do not lose sight of long-term benefits in favour of short-term gains. European institutions and countries can enter this sector due to having a positive reputation without the heavy political burdens and opinions attached to the U.S. and China. The region can provide important lessons and warnings to other newcomers in the space sector, highlighting the need for a focused and driven plan and execution, aiming to find a chance for cooperation and a specific field of expertise.

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# Remittances as a Vital Tool for Economic and Human Security in Latin America<sup>1</sup>

Amadea BATA-BALOG<sup>2</sup>

*While a wide range of extensive literature deal with migration as a security concern, much less attention is aimed at migrant remittances regarding security. However, vulnerable communities in developing regions such as Latin America tend to rely upon the sum of money received from migrants working abroad. In the shadow of the Covid-19 pandemic, it has again become apparent that migrant related monetary remittances play a vital role in disaster relief. In this paper it is argued that remittances have been a crucial tool for economic and human security in Latin America especially during the pandemic. Examining primary and secondary statistical sources, the analysis also tries to find explanations for the resilience and increasing volume of cross-border remittances with regard to the Latin American region, exceeding earlier estimates to a great extent.*

**Keywords:** *remittances, migration, security, Latin America, Covid-19*

## Introduction

It has become challenging to get along and navigate in our globalised world – one characterised by volatility, uncertainty, complexity and ambiguity (VUCA world) – that step by step presents profound challenges, requires different levels of management and leadership, as well as generates new dimensions of security needs.<sup>3</sup> “Secures” (Latin), i.e. “freedom from fear or anxiety” is something that many lack in developing regions, such as in Latin America and the Caribbean (LAC), where vulnerable communities tend to rely upon the sum of money received from family members and friends working abroad. Still in the shadow of the Covid-19 pandemic, it has again become apparent that migrant related remittances play an important role in disaster relief.

In fact, this global pandemic has been a disaster, hitting Latin America hard; 69 million infections and more than 1.6 million deaths have been documented.<sup>4</sup> Real numbers are even higher. The vaccination has been a priority in Latin American countries, at the same

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<sup>3</sup> Zeger van der Wal: *The 21<sup>st</sup> Century Public Manager. Challenges, People and Strategies*. London, Palgrave Macmillan, 2017.

<sup>4</sup> Reuters Covid-19 Tracker: Daily Statistics in Latin America and the Caribbean. *Reuters*, 15 July 2022.

time, monetary remittances from abroad turned out to be an “alternative serum” for the region. Surprising and reassuring data show that remittances in the LAC region have been extremely resilient under Covid-19 so far, helping millions of families to cope with the hardships during the fight against the pandemic.

Seeing the biggest declines in April 2020, the World Bank forecasted a 20% drop in remittances for low- and middle-income countries (LMICs) by the end of 2020, and a 19.3% contraction in Latin America, the sharpest decline in recent history that would have been about four times the decline in remittances experienced during the 2008–2009 global economic crisis.<sup>5</sup> The pessimism was though justifiable, as it was foreseeable that the epidemic would reduce employment and/or the wages of migrant workers as a result of the pressure on the labour markets of the host countries. However, despite forecasts, remittance flows quickly recovered, at least in some regions.<sup>6</sup>

In this paper it is argued that migrant remittances have been a crucial tool for economic and human security in Latin America during the Covid-19 pandemic. Also, the aim of the analysis is to find explanations for the resilience and increasing volume of cross-border remittances with regard to the LAC region, exceeding earlier estimates to a great extent. The research conducts secondary analysis of primary and secondary statistical sources especially focusing on the period between 2019 and 2022, while the study also offers a theoretical background by bringing migration, remittances and security to a common ground. It then provides a brief overview of the dominant migration trends in Latin America, followed by the chapter presenting remittances that have produced a surprising turnaround in the region during the pandemic.

## Migration, remittances and security

Within the field of security studies, the cross-border movement of people emerged as a key issue in the context of the geopolitical dislocation following the Cold War and also by wider social and political shifts associated with ‘globalisation’.<sup>7</sup> Ever since, a wide range of security theories and extensive literature deal with migration as a security concern,<sup>8</sup> while much less attention is aimed at migrant remittances regarding security.

“Migration is increasingly interpreted as a security problem”,<sup>9</sup> however, its interpretation and level of analysis differs. Security discourse has broadened and involve strategic and humanitarian approaches to the migration–security nexus, bringing state-centric security and human security to the table.<sup>10</sup> Without deeper introduction of the concept of “security”,

<sup>5</sup> KNOMAD: Covid-19 Crisis Through a Migration Lens. *Migration and Development Brief* 32, April 2020.

<sup>6</sup> KNOMAD (2020): op. cit.

<sup>7</sup> Philippe Bourbeau: *Handbook on Migration and Security*. Cheltenham, Edward Elgar Publishing, 2017.

<sup>8</sup> Didier Bigo: Security and Immigration: Toward a Critique of the Governmentality of Unease. *Alternatives*, 27, no. 1 (2002). 63–92; Khalid Koser: When is Migration a Security Issue? *Brookings*, 31 March 2011; Fiona Adamson: Crossing Borders: International Migration and National Security. *International Security*, 31, no. 1 (2006). 165–199.

<sup>9</sup> Bigo (2002): op. cit.

<sup>10</sup> Jef Huysmans – Vicki Squire: Migration and Security. In Myriam Dunn Cavelty – Victor Mauer (eds.): *Handbook of Security Studies*. London, Routledge, 2009.

this section cites the internationally known security theory of Buzan, Ole Wæver and Jaap de Wilde<sup>11</sup> and a few thinkers on human security in order to ultimately relate to migrant remittances.

Buzan offers a broader framework of security by specifying the levels and sectors of security. The three levels are individuals, states and international systems, and the increasingly overlapping sectors – often looked at as a matrix – are the ones of political, military, economic, societal and environmental. Remittances on an individual level mostly connects to economic security, which is defined by Buzan et al. as “concerns access to the resources, finance, and markets necessary to sustain acceptable levels of welfare (and state power)”.<sup>12</sup> Since the Copenhagen School of International Relations (dominated by Buzan himself and his colleagues) rather understood ‘societal security’ that concerns especially the identity of a society, according to their conceptualisation, migrant remittances are less related to this sector, even though they too have social substance.

As far as individual security is concerned, Buzan considers “life, health, status, wealth, freedom”<sup>13</sup> amongst others to be the main foundations. Yet it was Booth, who positioned human beings at the centre. He claimed that “security means the absence of threats” i.e. people (as individuals and groups) being “free from those physical and human constraints which stop them carrying out what they would freely choose to do”.<sup>14</sup> He listed threats such as poverty, poor education, political oppression, or war. Hampson a bit later defined the term “human security” in an even broader sense that includes economic, environmental, social and other types of harm to the overall livelihood and well-being of individuals.<sup>15</sup> Along these lines, remittances can be considered a tool to support, preserve and restate human security – especially when the state misses to do so. In fact, in the absence of state involvement – such as the existence of an efficient social security system – many people in developing countries, especially the poor and vulnerable, can only cope with security threats relying on migration-related remittances.<sup>16</sup>

Indeed, facing modern time challenges of security, the focus shifted from national security to individual and human security. According to the concept of human security identified by the UN, instead of the security of the state (military protection, state interests and territorial possession), the emphasis should be placed on the security of individuals (their well-being, access to food, education and work).<sup>17</sup> This is where remittances most

<sup>11</sup> Barry Buzan – Ole Wæver – Jaap de Wilde: *Security. A New Framework for Analysis*. Boulder, Colorado, Lynne Rienner Publishers, 1998.

<sup>12</sup> Buzan et al. (1998): op. cit. 8.

<sup>13</sup> Barry Buzan: *People, States, and Fear. The National Security Problem in International Relations*. Chapel Hill, University of North Carolina Press, 1983. 36.

<sup>14</sup> Ken Booth: Security and Emancipation. *Review of International Studies*, 17, no. 4 (1991). 313–326.

<sup>15</sup> F. Osler Hampson: Human Security. In Paul D. Williams (ed.): *Security Studies. An Introduction*. New York, Routledge, 2013. 279–294.

<sup>16</sup> Hai Anh La – Ying Xu: Remittances, Social Security, and the Crowding-out Effect. *Journal of Asian Economics*, 49 (2017). 42–59.

<sup>17</sup> Ivett Szász: A humánbiztonság koncepciója és mérésének lehetőségei. *Nemzetbiztonsági Szemle*, 7, no. 2 (2019). 109–127.

commonly appear in both security and migration related research; how they sustain livelihoods,<sup>18</sup> their impact on poverty, labour or food security/insecurity.<sup>19</sup>

Human security and national security are not competing concepts, but complementary concepts when analysing such complex issues.<sup>20</sup> Therefore, looking beyond the individual level, the effects of remittances (their size or their absence) can be examined on a state and an international level as well. When analysing economies and repressive regimes like the Venezuelan with the dictatorial rule of Nicolas Maduro,<sup>21</sup> the matter of the fact is that remittances – beyond their will – actually contribute to upholding the system on the brink of collapsing.<sup>22</sup> In this sense, the absence of remittances would be a threat on national security; not only an economic, but also a political security threat for the state. Being aware of the size of remittances received in the LAC region (as to be presented in the following sections), that often represent a vital source of foreign currency for developing countries, as a matter of fact, their extensive reduction would possibly result in regional security threat.

Back to Buzan et al., in order to study problems in the broadest sense, they also introduced the concept of the “regional security complex”, their main conceptual innovation. It was the regional level of analysis that was given the main consideration in their work, noting that the pattern of security interdependence is normally characterised by regional fragmentation.<sup>23</sup> This is often particularly accurate when dealing with migration trends in several regions, however, it is not without question how regions are divided. According to Buzan, the American continent is divided into North and South America, while the latter has two subcomplexes; the North Andean and the Southern Cone. The geopolitical division has been questionable ever since. For instance, by no means can the United States be divided into a separate regional complex from Mexico, the Central American isthmus and the Caribbean, because as a hegemon (superpower according to the theory) it plays a dominant role in intra-regional military, political and economic aspects, the latter including LAC remittances (again to be seen later). Although most international migration takes place between countries in the same region<sup>24</sup> – see Latin American interregional migration for instance – migration is global in that sense too, that migratory routs are diverse and cross-border migration in fact often also cross regions and continents. So do migrant remittances in our globalised world with technological advances, in which for capital transfers national borders are easy to bridge.

<sup>18</sup> Patricia Weiss Fagen – Mican N. Bump: Remittances in Conflict and Crises: How Remittances Sustain Livelihoods in War, Crises, and Transitions to Peace. *The International Peace Academy, Policy Paper*, February 2006.

<sup>19</sup> Jorge Mora-Rivera – Edwin van Gameren: The Impact of Remittances on Food Insecurity: Evidence from Mexico. *World Development*, 140 (2021).

<sup>20</sup> Szászi (2019): op. cit.

<sup>21</sup> Maduro, scapegoating the United States with its imperialism and multinational companies has made Washington responsible for all the trouble of the Venezuelan situation, marking the U.S. itself as a threat. Owing to the region’s specific anti-U.S. sentiment, the Venezuelans (the audience) are actually accessible through such communication (the speech act). On the other hand, the lack of press freedom and coercion also contribute to the securitisation ‘success’.

<sup>22</sup> Shannon O’Neil: Venezuelan Remittances Don’t Just Save Lives. *Bloomberg*, 04 April 2019.

<sup>23</sup> Buzan et al. (1998): op. cit.

<sup>24</sup> UN: Population Facts, No. 2017/5.

Whereas the migration and development nexus are subject to intense debate in modern sciences, in fact social stability can be shaken by waves of immigration.<sup>25</sup> However, in case immigration is “securitised”, i.e. interpreted as an existential threat by authorities and politicians (the securitising agent),<sup>26</sup> it makes it difficult to integrate immigrants into the receiving society.<sup>27</sup> Consequently, if economic integration is likely to fail, migrants will have less favourable circumstances to send remittances to their motherlands.

After such occurrences as the 2008 financial crisis and the latest coronavirus, it must have become even more evident that our world is highly interconnected, all issues have global implications. The recognition that what may affect only one actor at first, when a new development occurs, may ultimately affect everyone, directly or indirectly, in one way or another puts security – and its conceptualisation – in a whole new perspective.<sup>28</sup> How the world – in all levels – struggled to survive Covid-19, and uphold relative security is unprecedented. Latin America has (also) been deeply struggling, great challenges were experienced by its population; both its international migrants, as well as those who stayed at home.

## Latin American migration outlook

The migration landscape of Latin America has undergone profound changes in the last decades in terms of direction, intensity and composition of migratory flows. What is seen in the post-world war Latin America is that the direction of migratory flows changed; the region has transformed from being an immigrant receiving region to one that let go of a huge emigration population.<sup>29</sup> About 42.7 million people in the region live outside their country of birth.<sup>30</sup> These emigrants represents about 15% of all migrants around the globe (281 million); twice as much as the Latin American share of the world’s population.<sup>31</sup> The high migration potential that characterises the region (the Caribbean has the highest potential in the world in terms of actual readiness to migrate) is a sign that many more are planning to leave their homeland.<sup>32</sup>

Three fundamental migration processes can be identified regarding the LAC region:

1. South–North migration particularly to the United States;
2. Transatlantic (and transoceanic) migration mainly to Europe; and
3. Intra-regional migration, i.e. migration

<sup>25</sup> Péter Marton: *Biztonsági komplexumok. A biztonság empirikus elemzésének alapjai*. Corvinus University of Budapest, 2019. 101–112.

<sup>26</sup> Buzan et al. (1998): op. cit. 23–31.

<sup>27</sup> Ariane Chebel d’Appollonia: *Securitization and Integration. In Migrant Mobilization and Securitization in the US and Europe*. New York, Palgrave Macmillan, 2015. 63–90.

<sup>28</sup> Péter Marton: A biztonság empirikus elemzésének újragondolása. *Nemzet és Biztonság*, 10, no. 6 (2017). 61–78.

<sup>29</sup> Thomas Skidmore: *Modern Latin America*. Oxford, Oxford University Press, 2005.

<sup>30</sup> Jairo Acuña-Alfaro – David Khoudour: El potencial de la migración en América Latina y el Caribe. *UNDP, Programa de las Naciones Unidas para el Desarrollo*, 20 January 2020.

<sup>31</sup> Dany Bahar – Ernesto Talvi: Can Latin American Countries Benefit from their Large Emigrant Populations? *Brookings*, 30 March 2018.

<sup>32</sup> IOM: *Measuring Global Migration Potential, 2010–2015*. IOM’s *Global Migration Data Analysis Centre*, July 2017.



within the region itself, which is currently the most pronounced trend due to the Venezuelan humanitarian and migratory crisis.<sup>33</sup>

The most striking feature of the region's main migration routes has been the predominance of the United States as the prime destination country. This is because most migration routes in fact lead to the U.S. (mainly from the Caribbean and Mexico), while other relevant movements take place within Latin America and the Caribbean. Six out of ten international migrants living in Latin America were born in the same region.<sup>34</sup> Following the 9/11 terrorist attacks – which resulted in the serious rethinking of the concept of security – tighter immigration regulations were implemented in the U.S., then later due to the economic crisis of 2008 that hit developed countries hard (especially Spain, for example), interregional migration flows increased in the LAC region. The main destinations have become the strong economies of South America, Argentina, Chile, Brazil or Colombia.

With the emergence of south–north migration corridors on the American continent, the waves of massive immigrant populations accelerating from the 1980s to the 1990s laid the foundations for the establishment of significant foreign colonies in the United States that still exist today. Moreover, thriving diasporas – as a “pull” factor – continue to attract those who remain in the homeland. Immigration from Latin America to the United States and Canada accounted for 43.2% of total inflows in 2020, meaning that more than 25 million Latin American migrants live in North America.<sup>35</sup> Another statistic worth noting is that nine out of ten immigrants received by the U.S. are from El Salvador and Mexico.<sup>36</sup>

European colonising countries are popular destinations for those wishing to leave Latin America. More than half of Latin America's migrant population residing in Europe lives in Spain (2.5 million<sup>37</sup>), while immigration to Italy, Portugal and the United Kingdom has also become popular in recent decades. Although only 6.1% of immigration to Europe comes from the region, there are still around 4.6 million Latin American immigrants in the old continent, this group is characterised by a high concentration of the productive age and a predominant presence of women<sup>38</sup> (feminisation of migration).<sup>39</sup> Emigration to Europe comes mainly from Ecuador, Colombia, the Dominican Republic, Argentina, Peru, and to a fewer extent from Venezuela.<sup>40</sup> Even though the global economic crisis has certainly curbed the number of people arriving in Europe for a short time, it has not led to a remigration of the Latin American population. The economic recovery has boosted inflows again, and the total number of immigrants in Europe is still growing today as

<sup>33</sup> Jorge Durand – Douglas Massey: *New World Orders: Continuities and Changes in Latin American Migration. The Annals of the American Academy of Political and Social Science*, 630, no. 1 (2010). 20–52.

<sup>34</sup> UN (2017): op. cit.

<sup>35</sup> IOM: *Informe sobre las migraciones en el mundo 2020*.

<sup>36</sup> BID: *Flujos Migratorios en América Latina y el Caribe. Banco Interamericano de Desarrollo*, September 2021.

<sup>37</sup> INE: *Población por nacionalidad. Instituto Nacional de Estadísticas*, 2021.

<sup>38</sup> Jordi Bayona-i-Carrasco – Rosalia Avila-Tápies: *Latin Americans and Caribbeans in Europe: A Cross-Country Analysis. International Migration*, 58, no. 1 (2020). 198–218.

<sup>39</sup> Gabriella Thomázy – Amadea Bata-Balog: *Colombianas en Chile: tendencias y determinantes de la migración femenina. Acta Hispanica*, 25 (2020). 23–35.

<sup>40</sup> Mónika Szente-Varga – Amadea Bata-Balog: *Return Migration from Venezuela to Europe: Back to the Roots. Estudios Internacionais*, 9, no. 3 (2021). 75–95.



a result of the rapid increase in the influx of refugees in recent years. One of the biggest, if not the biggest, security threat for Europe and the whole world is the ongoing Russian invasion on Ukraine, which has let almost 7 million citizens leave their country.<sup>41</sup> The Ukrainian refugee crisis again distracts Europe from the critical migration situation of Latin America.

While Latin American emigration to Asia and Oceania (including Australia and New Zealand) is also slightly increasing (mainly from Brazil), intraregional migration flows have been streaming even more intensely. The term ‘unprecedented’, often used by experts, illustrates the severity of the migration crisis that has characterised Latin America in recent years, facing two dominant flows. One is migration from Central America to the United States via Mexico from the “northern triangle” of Honduras, El Salvador and Guatemala. Since 2014, it is estimated that 265,000 migrants in transition have intended to settle in the U.S. from these countries each year, 80% of whom are detained by Mexican or U.S. authorities.<sup>42</sup> As a result, the phenomenon of return migration is also increasing, mainly from Mexico. The second wave of migration crises originates from Venezuela, a country once used to be one of the richest in the region, yet today it is in a catastrophic economic, political and social situation. Until 2022, the UN High Commissioner for Refugees counted 6,133,473 million emigrants (as of 5 May 2022), of which 84%, i.e. about 5 million Venezuelans found their permanent or temporary new “homes” within the region, still millions residing with irregular status.<sup>43</sup> The countries receiving the largest share of the influx are Colombia, Peru, Chile and Ecuador. Such an exodus – with an estimation of 9 million displaced people by the end of 2022<sup>44</sup> – is indeed posing enormous challenges for host and transit countries and a great security threat to the region, especially considering that it is deeply underfunded by the international community.<sup>45</sup>

## Remittances in the LAC region before and during the pandemic

Latin American migrants outlined above support the development of their homeland in three main ways, namely through business and social networks, the dissemination of knowledge and technology, and monetary remittances. This study focuses on the latter, and its development during Covid-19. Remittances sent from abroad – on a regular or occasional basis – to those who have remained at home, are mentioned in the (re) migration literature in the context of utilitarian strategy on the one hand, and in the system of transnationality and networks on the other.<sup>46</sup> International remittances are thus an important and spectacular link between migrants and the society that sends them. They

<sup>41</sup> UNHCR: *Ukrainian Refugee Situation*. 2022.

<sup>42</sup> Acuña-Alfaro–Khoudour (2020): op. cit.

<sup>43</sup> R4V: *Inter-Agency Coordination Platform for Refugees and Migrants from Venezuela*. 2022.

<sup>44</sup> RMRP: *Regional Refugee and Migrant Response Plan*. R4V, 2022.

<sup>45</sup> Béla Soltész: A venezuelai kivándorlás hatása Dél-Amerika országaira. *KKI Elemzések*, no. 51 (2021). 3–14.

<sup>46</sup> Amadea Bata-Balog: A remigráció diskurzusa: A hazatérés mozgatórugóinak és fejleményeinek áttekintése – különös tekintettel a magyar nyelvű szakirodalomban. *Tér-Gazdaság-Ember*, 9, nos. 3–4 (2021). 49–68.

are considered to be a positive consequence of migration, in contrast to the negative effects of emigration, – such as labour shortages, brain drain or structural problems – especially influential in developing countries where these remittances account for a significant share of the total national income.<sup>47</sup> Great examples of this are the LAC countries, where remittances have risen steadily over the past decade and genuinely represent a salient component of their GDP (26.4% of GDP in El Salvador, 26.2% in Honduras and 23.6% in Jamaica).<sup>48</sup>

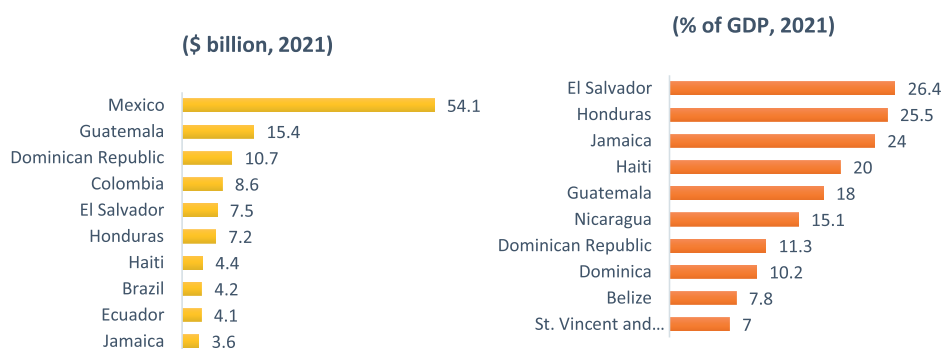


Figure 1: Top remittance recipients in the LAC region, 2021

Source: KNOMAD (2022): *op. cit.*

As a result of the pandemic, the total value of officially recorded international remittances in the world average fell moderately by 2.4% in 2020, despite dramatic forecasts, while remittances from low- and middle-income countries were “only” 1.6 % lower than the 2019 values.<sup>49</sup> According to KNOMAD, out of the six LMIC regions (see Figure 1), Latin America and the Caribbean was clearly with the most fruitful in terms of remittance growth after closing the first year of the crisis with an 8.2% increase, with incoming remittances reaching \$104 billion at the end of 2020.<sup>50</sup>

<sup>47</sup> Ninna Nyberg Sørensen: The Development Dimension of Migrant Remittances. *IOM*, June 2004.

<sup>48</sup> KNOMAD: A War in Pandemic 2022. *Migration and Development Brief 36*, May 2022.

<sup>49</sup> KNOMAD: Resilience. Covid-19 Crisis Through a Migration Lens. *Migration and Development Brief 34*, May 2021a.

<sup>50</sup> KNOMAD (2022): *op. cit.*

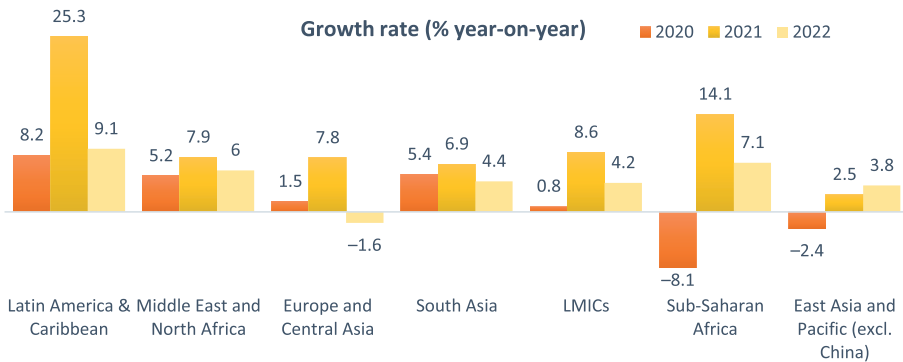


Figure 2: Remittance flows by LMIC region, 2020–2022

Source: KNOMAD (2022): *op. cit.*

Although the Covid-19 shock initially led to an expected decline, remittances rapidly bounced and many Latin American countries have reported that their monthly remittance flows not only have recovered since April 2020 but are even higher than they were before the pandemic. By 2021, we see that remittances further catch-up, and we can witness a 37% increase in Guatemala, 34% in the Dominican Republic, 33% in Honduras, 31% in Salvador, 26% in Colombia, 25% in Mexico and 24% in Jamaica compared to the previous year. We could continue the list with South American countries regaining their strengths in terms of remittances, like Brazil or Ecuador, while there are some negative examples as Panama or Paraguay, where remittance inflows could not catch-up so quickly. Nevertheless, on the top of the list there is Mexico, which is the second largest recipient of remittances in the world with nearly \$54.1 billion – only outstripped by India, followed by China – certainly leading the way in Latin America with huge amount of migrant remittances.<sup>51</sup>

Even before the release of last year's official year-end statistics, it was clear that the data for 2021 would reflect a further increase in remittances, and there were clear signs of another boom by 2022, as well. Revenues from remittances in the region indeed reached \$131 billion in 2021, an increase of 25.3% by the end of the year – again even exceeding the projected values.<sup>52</sup> Looking at the latest data of May 2022 – which already takes into account the effects and escalating risks of the Russian invasion of Ukraine – remittances to the LAC region are forecasted to propel by a strong 9.1% pace in 2022 and 7.7% in 2023.<sup>53</sup> However, downside risks dominate due to the war and its consequences on economic developments, austerity measures, inflation pressures and uncertain advancements in immigration policy in the United States, and further geopolitical risks.

<sup>51</sup> KNOMAD (2022): *op. cit.*

<sup>52</sup> KNOMAD: Recovery. Covid-19 Crisis Through a Migration Lens. *Migration and Development Brief 35*, November 2021b.

<sup>53</sup> KNOMAD (2022): *op. cit.*

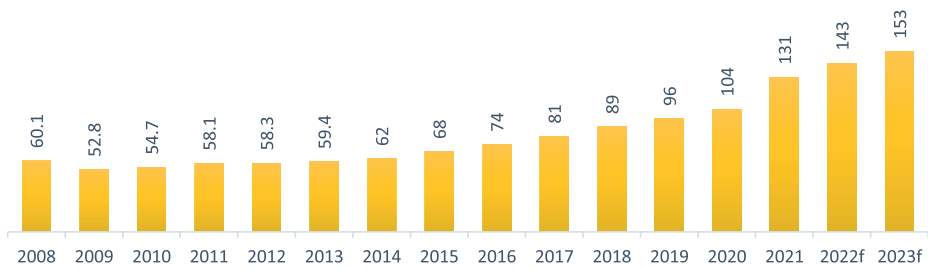


Figure 3: Migrant remittance flows to Latin America (2008–2023) billion \$

Note: f = forecast

Source: 2008–2014: CEMLA (2021): *op. cit.*; 2015–2023: KNOMAD (2022): *op. cit.*

## Interpretation of remittance developments

Migrants are particularly vulnerable to the economic and health effects of the pandemic, as they generally have limited access to the host country's state aid, social security system and often have occupations that suffer significant job losses during a crisis. In many cases, we see that the savings of immigrants are insufficient to protect their income during the current pandemic.

Thus, the question arises, how is it possible for migrants from certain countries to send home not less, but sometimes even more of their savings during the Covid-19 pandemic? The fact that remittances to Latin American countries were in a surplus was a pleasant surprise. How can this trend provoking early forecasts be explained? Some key factors help to reveal what happened.

First of all, more than 75% of remittances to the region come from the United States,<sup>54</sup> (and for some countries more than 90%)<sup>55</sup> as the U.S. is the number one destination for those leaving the LAC region. Although the employment rate of foreign-born workers in the States decreased by more than one-fifth in April 2020 compared to before the outbreak of the pandemic, the situation has steadily improved ever since. Immigrants tend to change jobs rather than stay out of work in the long run, so shifts to the necessary sectors during the epidemic have reduced the impact of the employment crisis. All this, as well as various aids, incentives and benefits provided by the government have improved economic conditions compared to the forecasts and allowed remittances to quickly recover. Meanwhile Spain's, the second largest host country for Latin American communities, economic situation had a negative impact on remittance flows to Bolivia (–16%), Paraguay (–12.4%) and Peru (–11.7%) in 2020.<sup>56</sup> Similarly, in the case of some countries, remittances

<sup>54</sup> Mariellen Jewers – Manuel Orozco: *Migrants, Remittances, and Covid-19. Remittance Behavior and Economic and Health Vulnerabilities*. Washington, D.C., Inter-American Dialogue, 2020.

<sup>55</sup> KNOMAD (2022): *op. cit.*

<sup>56</sup> Banco Mundial: *Los flujos de remesas desafían las previsiones y siguen siendo sólidos durante la crisis provocada por la Covid-19*. 12 May 2021.

within the region have significantly shrank due to the virus and restrictive measures that were particularly strict in the region. For example, remittances from Ecuador to Colombia, Mexico and Peru fell by 20% due to restrictive measures.<sup>57</sup> At the same time, with the emergence of new migratory routes, we are witnessing an increase in remittances within the region. The number one example is remittances sent from Colombia to Venezuela or money transferred to Mexico for Guatemalans, Salvadorans and Haitians on their way to the United States. Since transit migrants tend to stay in transit countries for a longer period, they need additional financial assistance from their families (either from their home country or those already living in the country of destination) to cover the cost of living and travel, and the payment of human traffickers. Therefore, we see that the inevitability and favourable development of remittances during the epidemic is felt primarily by the Central American and the Caribbean region, and secondarily by South American countries. In the South, the importance of these resources seems to be somewhat smaller compared to their own GDP (e.g. Argentina 0.2%; Brazil 0.3% or Colombia 2.7% in 2021),<sup>58</sup> yet they are an extremely important additional source of income to fight poverty.

Part of the explanation is that remittances are in fact ‘counter-cyclical’ in times of crisis. During periods of crisis (let it be a financial crisis or natural disaster), migrants try to send a large share of their income back to their home countries. This altruistic behaviour was also observed during the 2008 economic crisis, and this is reflected in the personal narratives of many Latin American migrants who say: “I will not stop helping my mother in any way, even if my income is declining”, as they note “we struggle here, but it is even worse at home”.<sup>59</sup> Although newcomers and those living in insecure situations often have unbalanced working conditions, diasporas living in key migration corridors are better prepared to sustain the level of remittances destined for people living in their country of origin in times of crisis.

Pandemic-related travel and movement restrictions and the closure of shops made it difficult to access physical remittance providers, such as returning cash. However, the proliferation of digital transfers, such as the use of digital money, and the shift from informal to formal channels have greatly contributed to avoiding a decline in trends. A Mexican case study, for example, found that in the municipalities close to the border, which previously received remittances through informal channels, the number of registered remittances and open bank accounts has risen to a record level since the beginning of the pandemic.<sup>60</sup> Both national and international banks have developed a variety of policies to help member states and migrants in sending remittances; reducing the costs, simplifying the process by implementing favourable transfer regulations.

While new migration flows and the number of refugees has declined, the crisis led to an increase in remigration. Initially, many migrants were stranded in their host countries due to lockdown measures and travel bans; however, as these were slowly lifted, a steady

<sup>57</sup> KNOMAD (2021a): op. cit.

<sup>58</sup> KNOMAD (2022): op. cit.

<sup>59</sup> Miriam Jordan: Even When They Lost Their Jobs, Immigrants Sent Money Home. *The New York Times*, 24 September 2020.

<sup>60</sup> Lelys Dinarte et al: Neither by Land nor by Sea. The Rise of Electronic Remittances during Covid-19. *World Bank Group*, May 2022.

increase is perceptible in the number of migrants that returned to their country of origin. Some also transferred their last savings home before making the trip, while the large increase in remittances may also be explained by the savings sent home of migrants who died in coronavirus infection.<sup>61</sup>

Another understanding of the size and evolution of remittances is related to the individualistic and collectivist nature of societies. Individualistic societies emphasise individual goals and individual well-being, while a collectivist, solidarity-based nation focuses on the goals of the group, in which the individual easily sacrifices his or her own interest. Personal, long-term relationships are becoming increasingly important, and migration networks, transnational and diaspora relationships are extremely strong. Latin American countries are characterised by such collectivism, while developed Western nations have rather individualistic identities. This also explains why during the pandemic the resources of Latin communities have been enriched, while the remittances to Western developed countries have usually subsided. Similarly, to other European countries, remittances in Hungary fell significantly from 2019 to 2020 (–25%),<sup>62</sup> ever since continued to drop according to the National Bank of Hungary.

The strengthening of oil prices helped the recovery of remittances and the economic recovery of the oil producing countries in the region, such as Brazil and Mexico. The resilience of remittances to the crisis is also shown by the fact that (except for China) the remittances targeted at low- and middle-income countries have evidently surpassed foreign direct investment (FDI) figures and three times the value of development aid (ODA).<sup>63</sup> It is visible that there has been an increase in the dependence on remittances in the Latin American region, mainly due to the deterioration of GDP and high rates of inflation. All in all, this could make these economies vulnerable to sudden changes in remittance revenues – as noted earlier, can culminate in economic security concerns. Nonetheless, the economic development potential of migrants' remittances is well known, given that this is practically the only quantifiable feature of migration.<sup>64</sup> However, the extent to which these transfers can offset the effects of the Covid-19 crisis in different countries is still questionable. Certainly, the outbreak of the coronavirus once again highlighted the importance of remittances, which continue to be a basic source of income for a significant share of the Latin American population and a vital mechanism to alleviate the negative effects of the severe pandemic.

## Conclusions

Remittances to the LAC region have been responsive in a positive direction. Although the epidemic has not yet ceased to exist by the middle of 2022, we see the tightening and lifting restrictions on mobility in sending and receiving countries that affect the

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<sup>61</sup> The Economist: Why the Pandemic Has Not Dented Latin American Remittances? *The Economist*, 02 December 2020.

<sup>62</sup> Eurostat: *Personal Remittances Statistics*. 2021.

<sup>63</sup> KNOMAD (2021a): op. cit.

<sup>64</sup> Nyberg Sørensen (2004): op. cit.

recovery of post-Covid economies, the size and direction of legal and irregular migration flows, and thus the development of migrant remittances, as well. Indeed, LAC emigrants have maintained strong connections with their home countries, sending home sizable remittances before, during, as well as after the global pandemic. Remittances to Latin America are expected to further increase in 2022 and 2023, however, downside risks are also present due to the impact of the war between Russia and Ukraine, geopolitical uncertainties, improvements depending on economic developments, the inflation pressures in Western societies and dilemmas regarding immigration policies (especially concerning the U.S.).<sup>65</sup> Further growth will require greater progress in accessing bank accounts for the immigrant population (which is essential for the use of digital channels) and there will be a high demand to reduce the cost of remittances. The 2030 target is to reduce the costs by almost half, since transferring money across international borders is persistently high, although it is lower in the LAC region than the global average.<sup>66</sup>

Despite the importance of intraregional migration, countries of the region are not large senders of remittances compared to the remittances they receive<sup>67</sup> – yet these transfers are also decisive in their amount and effects. More importantly, the data and its analysis have mirrored the importance of the conditions of the U.S. economy for remittances to the region. However, the increase in remittances in 2020–2022 also well reflects the collectivist nature of the Latin American population, the effort and commitment of migrants (altruists) to maintain support for their relatives left in their countries of origin, especially in critical times such as a crisis caused by a pandemic. Those who remain at home need revenue in particular to finance their medical services during the pandemic, especially considering that the underdevelopment and overcrowding of public health in the region often requires the use of private institutions. By its nature, remittances function as a channel to reduce poverty and inequality,<sup>68</sup> in case there was a decline in remittances, the living conditions of those in the Latin American region would continue to deteriorate, which would encourage further emigration. Both resulting in security threats either for individuals themselves or at the regional level as well. Especially during the Covid-19 pandemic, when the vulnerable population has experienced great uncertainties, remittances turned out to be an essential form of social insurance and a kind of livelihood diversification.<sup>69</sup> Money transferred home has been a vital economic lifeline, helping millions of families in Latin America more resilient to shocks – like the economic and social effects of the pandemic – providing remittance recipients support to mitigate risks.

Although remittances have the potential to reduce livelihood security risks of the recipients, while also displays visible development effects on the recipient economy, it is vital to realise that the responsibility for the citizens' social security and development lies with states and not migrants.<sup>70</sup> Nevertheless, the leaders of the countries representing the

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<sup>65</sup> KNOMAD (2022): op. cit.

<sup>66</sup> KNOMAD (2022): op. cit.

<sup>67</sup> Kimberly Beaton et al.: Migration and Remittances in Latin America and the Caribbean. *IMF Working Papers*, 144 (2017).

<sup>68</sup> Beaton et al. (2017): op. cit.

<sup>69</sup> Laura Thompson: Financial Remittances – A Tool for Development? *IOM*, 16 October 2014.

<sup>70</sup> Thompson (2014): op. cit.

world's major economies, –including the main destination countries of LAC migrants –have committed themselves “to take steps to support the full inclusion of migrants [...] in our pandemic response and recovery efforts [...] regardless of their migration status”.<sup>71</sup> In the framework of the G20 Rome Summit they reaffirmed to “strongly encourage the continued facilitation of the flow of remittances and the reduction of average remittance transfer costs”.<sup>72</sup>

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<sup>71</sup> GPMI: *G20 Rome Leaders' Declaration*. 2021.

<sup>72</sup> GPMI (2021): op. cit.



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