Development of Integrated Forest Fire Prevention System

LAYMAN RIPORT

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There are countries in Europe that have long struggled with the challenges of forest and vegetation fires due to their geographical location. In addition, there are countries, including Hungary, that have encountered increased problems of forest and vegetation fires in recent decades due to climate change and land use changes.

Hungary is part of the most vulnerable region of Europe in terms of climate change, so it is particularly affected by global warming. The 1.4-1.9 degree increase previously predicted for 2050, compared to the annual average temperature 100 years ago, was already achieved by 2010. Due to its basin location and continental climate, drought periods are getting longer. Due to climate change and the land use conditions that changed in the 1990s, the number and extent of forest and vegetation fires have increased significantly in the past two decades, and there are more and more extreme forest fire events, which often affect already inhabited areas.

In 2023, 2,733 forest fires affected 21,000 hectares of forest. The number of vegetation fires affecting wooded areas was several times this. Based on climate models, the length of fire-prone periods, the intensity of fires and the number of fires will also increase in the coming period. Of course, there will be years with more favorable weather, but the direction of the trend is clear. Forest and vegetation fires always cause significant emissions, but this is especially serious in intensive crown fires, which also result in habitat degradation and the release of significant amounts of carbon bound in the upper part of the soil. In 2024, due to weather extremes, the risk of forest fires also appeared in areas of Hungary where it was not typical before. The extent of the Csöngei forest fire exceeded 1,000 hectares, i.e. 10,000,000 square meters!

The fire risk of drought-tolerant target stands is also higher. The results of the afforestation program reach their most vulnerable age in terms of forest fires within 2-5 years. 99 percent of fires are caused by humans, which is both sad and gives a chance for protection.

One important goal is to prevent fewer forest fires, and the other is to ensure that the resulting forest fires spread more slowly and are extinguished more quickly. The project uses international good practice and domestic fire prevention, green fire prevention and fire modeling research results, communication and training experiences.

Effective forest and vegetation fire protection requires the cooperation of many disciplines, and in many areas, a paradigm shift is necessary due to changed environmental conditions, or in the best case, a modification or addition to current practice.

Project objectives

The most effective and cheapest way to control forest and vegetation fires is prevention. Forest fire prevention activities can be divided into three main groups of activities. The first is the prevention of power fires, which is served by communication and training programs; The second is the detection of fires as soon as possible, and the third is the prevention, slowing down and containment of fires with prevention facilities and fire-fighting infrastructure.

Ignác Darányi plan to announce the forest fire prevention title of the new Hungary rural development program The Forest Fire Prevention Working Group of the Faculty of Forest Engineering has developed the technical documentation and cost calculation for water fires for narrow ground and air fires.

However the requirements for a wide range of firebreaks has not been developed.

During the preparation of the Rural Development Program 's Prevention of Forest Damage Caused by Forestry Potential, the inclusion of wide (type D) fire break in the program was also raised in the tender, however, the system of technical requirements for type D fire break and the related fire spread background calculations were not available. In addition to the system of technical requirements, it is also necessary to determine the location of wide firebreaks, as these firebreaks serve the protection of forests and the population at the forest planning district level.

In Hungary, 99 percent of the resulting forest and vegetation fires are caused by human negligence. A smaller proportion of the fires are the result of deliberate arson, but unfortunately the cause of forest fires has also been included in the means of terrorists, so the development of an appropriate fire control system is also suitable for eliminating and reducing such risks.

Due to climate change, the intensity of fires has increased significantly in the last decade, as well as the jumping potential of surface fires. The fires that previously spread to the surface very quickly develop into intense crown fires, and the extent of the crown fires that occur is constantly increasing. Due to their size, intensity and the amount of burning biomass, intense surface and crown fires can no longer be extinguished with the traditional so-called direct water extinguishing tactics, firebreaks are essential to slow them down and curb them and to build protection against them. Existing and designed narrow firebreaks cannot be connected to a complex protection system because there is a lack of wide firebreaks and green firebreaks to which narrow firebreaks can be connected as main lines of defense. In case of unfavorable wind conditions, in the drought caused by the heat wave of July-August 2017 or by the Historic drought in 2022, a crown fire in Kelebia can spread to Kecskemét due to the lack of a wide fire-retardant system.

A forest fire that will destroy hundreds of hectares, unfortunately thousands of hectares in 2012, will cause enormous damage to foresters, who will destroy their crops if they remain burned, it will be difficult or impossible to sell them and there will be additional costs to regenerate. large-scale reforestation is also microclimatically unfavorable and more vulnerable than in the case of progressive forest management without forest damage.

Unfortunately, the fire risk has not decreased, but has increased since the project plan was first submitted. Even in Vas County, which previously had a low fire risk, the forest fire destroyed an area of more than 1,000 hectares on the outskirts of Csönge.

In addition to the economic damage to the forest manager and nature conservation manager (National Park), the ecological damage is even more significant, as the regeneration of some forest associations and even grassland associations takes decades or even a century after a high-intensity fire.

Due to climate change, more and more drought-tolerant but more fire-risk forest stands will be renovated and planted in Hungary in the next decade.

Results to be achieved

Determination of technical design and maintenance parameters of type D wide fire breaks based on current and expected weather conditions, weather extremes, stock conditions, using fire propagation model calculations.

Determining the technical design and maintenance parameters of type D fuel breaks based on the current and expected weather conditions, weather extremes, stock conditions, with the help of fire propagation model calculations.

Development of a set of rules for the placement of type D wide fire breaks and fuel breaks.

Preparation of sample plans for the design of fuel breaks as a function of site conditions and nature conservation requirements based on the evaluation of sample areas and model calculations.

Establishment of the route of a type D firebreaks system in Bugac forest planning district.

Description of silvicultural work processes, formation of specific cost data, compilation of cost calculations based on the results of the research.

Description of wood use and maintenance work processes, formation of specific cost data, compilation of cost calculations based on the results of the research.

Determination of design and maintenance costs for type D firebreaks and fuelbreaks.

Initiating the modification of forest fire prevention plans in Bács Kiskun county.

Climate models

As a first step, we created datasets that model the changes in the aridity index developed for forestry purposes on a national scale in the 21st century. The maps below show how the characteristic value of the forest climate type classification is expected to change in the country for the examined time intervals based on climate model data. The extent of the change is given by the change in the FAI value calculated from macroclimatic data. The unit of change on the maps is the same as the extent of a climate class in FAI values (1.25 FAI units).

The maps thus show the direction and extent of climate change in the future. The maps were prepared for three periods (2011-2040; 2041-2070; 2071-2100) and two emission scenarios – RCP 4.5, RCP 8.5 (Figures 1-3). Overall, we can conclude that in the case of a climate change trajectory no worse than the 4.5 emission scenario, there may be a realistic chance to maintain reasonable forest management activities, including efforts to prevent forest fires, but significant adaptation steps must be taken for this as well.

The implementation of the 8.5 scenario would have a catastrophic impact on forest management, and even raises serious doubts about the extent to which tree-covered habitats could be maintained in the country. Thus, we did not continue the data analyses for forest fire prevention in the pessimistic scenario, since in this case the forest areas of the Great Plain would become unsustainable in the very short term. Therefore, we examined the climatic parameters determined based on climate models based on the RCP 4.5 scenario in the production of map files related to forest fire exposure.

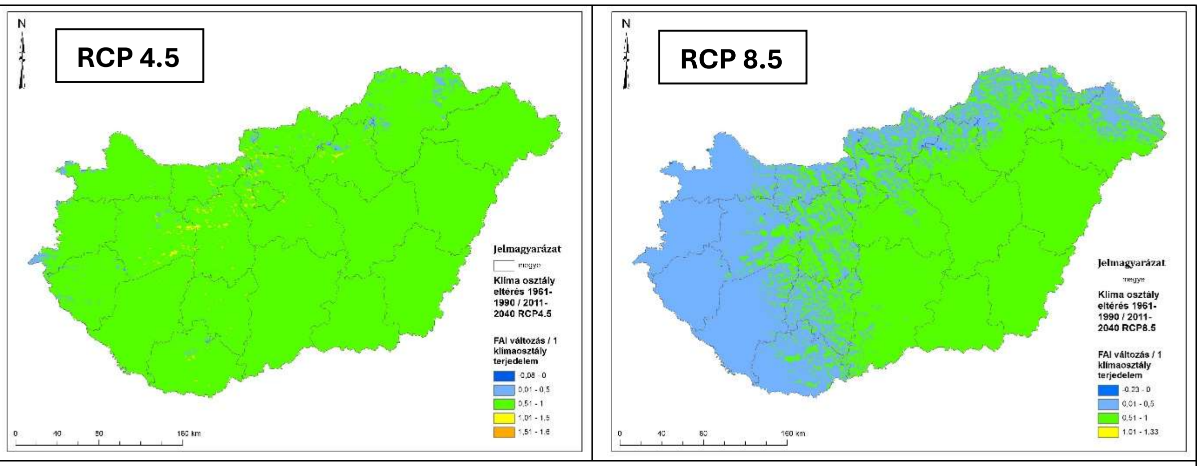

Figure 1: Climate class change between 2011-2040 compared to the period 1961-1990

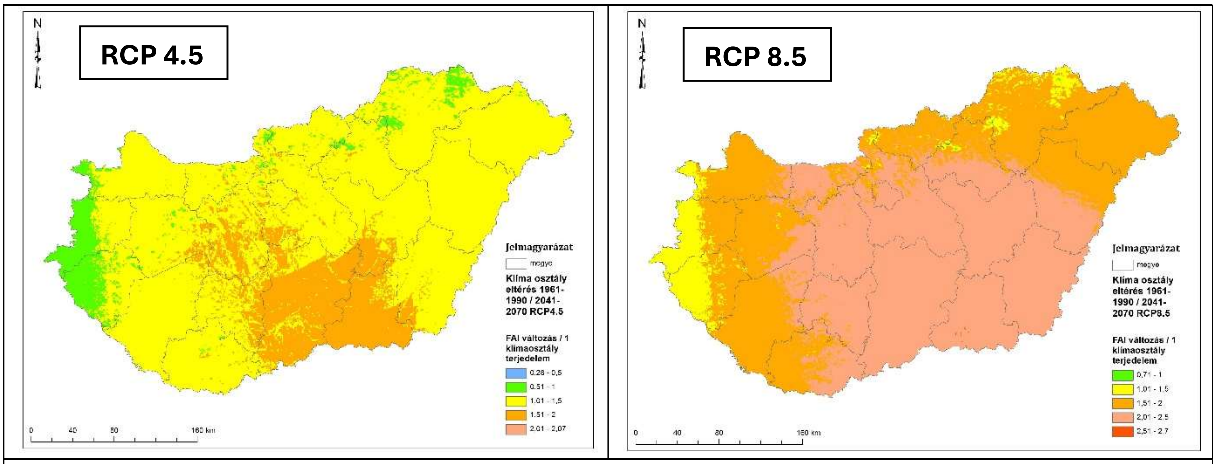

Figure 2: Climate class change between 2041-2070 compared to the period 1961-1990

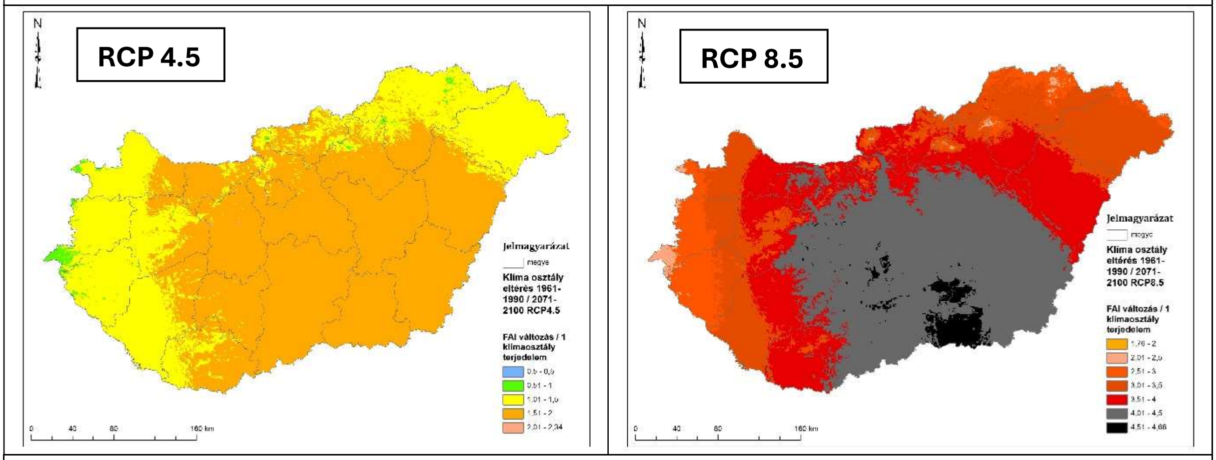

Figure 3: Climate class change between 2071-2100 compared to the period 1961-1990

Climate change already affects the risk conditions of forest and vegetation fires in the medium term. It increases the length of fire danger periods, modifies the growth conditions of plant communities, shifts the forest climate classes, increases mortality and the amount of dead biomass. In the short term, we can primarily encounter weather extremes.

Weather extremes

In addition to the medium-term effects of climate change, in the short term, from a forest fire spread and modeling perspective, we must primarily take into account the meteorological parameters characteristic of extreme weather conditions related to climate change. Unfortunately, the unfavorable trend of weather in terms of forest fire spread is clearly visible in several weather data. In the past decade, we have encountered not only seasonal, but also droughts that have lasted for years (2021-2022). Of course, drought periods appear in forest fire data if they develop in parts of the country that are also at risk from forest and vegetation fires. The relevant data from the point of view of forest fires is the length of continuous periods without precipitation, since if such a period occurs in spring or summer, it will certainly result in a decrease in biomass moisture content to a critical level. Unfavorable years occur cyclically. If the period without precipitation is longer than 25-30 days, then even the so-called 1000-hour dead biomass can dry out, which results in fires that are more difficult to extinguish. It can be concluded from the data series that the length of such periods is increasing in a trend. The average summer temperature is also trending higher, but there are extremely outlier years when the increase can be as much as 4-5 degrees. These years also produce outlier forest fire data.

Fire spread modeling

In order to determine the technical parameters of wide fire belts by taking climate change and weather extremes into account, using conservative risk estimation methods, the dynamic fire spread properties of the resulting forest fires must be modeled. For fire spread model calculations, we need to have characteristic data sets of the fire environmental triangle (weather, biomass, topography). The most labor-intensive process was the compilation of biomass models. There are no significant differences in altitude above sea level in the Bugac forest planning district, but micro-topography conditions can locally accelerate fire spread and may be sufficient to transform a surface fire into a crown fire, especially if the forest stand contains so-called biomass or species with significant jumping fire potential occur.

The study consisted of the following work phases:

• preparation of biomass models for EF, FF, EF-FF, Leaf litter EF and FF stands and juniper summer stands;

• compilation of input parameters of the fire spread model;

• running the fire spread model;

Biomass sampling

To review the static parameters of the biomass models, we had to select the sampling methods applicable to local (vegetation, technical and financial) conditions. After selecting the sample areas characteristic of each model type, the exact location of the quadrats was determined with a randomly laid out (100x100 meter) raster grid, and then the sampling location was measured with a GPS device. The minimum number of samples was determined using mathematical statistics methods, taking into account the standard deviations expected in fire modeling.

Two methods were used for the survey:

Quadrat sampling for the duff layer, the foliage and needle layer, and the herbaceous vegetation. If the amount of woody dead biomass at the sampling site is low, this was also surveyed using the quadrat method. The size of the quadrat varies between 0.25 m2 and 1 m2.

	
Figure 4. Square sampling with a 0.25 square meter grid	Figure 5. Square sampling with a 1 square meter grid l

One-dimensional line method

We used a one-dimensional line method to record larger amounts of dead woody biomass. The one-dimensional line method is actually a strip method with negligible width. The recording line is actually an imaginary vertical plane, and all dead woody biomass elements intersecting this plane are recorded. Of course, the real intersection of the biomass piece and the plane is usually an ellipse, but from the point of view of recording we can treat it as a circle. We did not measure the diameter of each individual biomass piece, but diameter groups were created. These diameter groups correspond to the moisture equilibrium categories used for biomass moisture content changes, i.e. the grouping of biomass elements following the atmospheric moisture content change over 1, 10, 100, and 1000 hours. Each diameter is measured in the 1000-hour biomass diameter group.

Figure 6. Linear sampling with a “go-no-go” device

Figure 7. Linear sampling with combined recording using a “go-no-go” device

Standing at the point with the specified coordinates, we set out the recording axes 1-4 at 90 degrees from any starting azimuth, numbering them 1-4. The length of each axis is 20 meters, and these were marked with a special rope with divisions every 5 meters. Depending on the biomass amount and diversity, the quadrats were recorded at the 5-meter breakpoints. While in the linear method, moving away from the starting point, all size groups were recorded in the first section, size groups 2,3,4 in the second, size groups 3,4 in the third section, and only size group 4 in the 4th section.

Surface fire spread model

After compiling the input data for the fire spread model, the fire spread parameters of each revised biomass model were checked using the BEHAVE software.

We used weather parameters compiled with a conservative approach for the fires, taking into account the possible extremely hot, dry spring/summer weather in the area.

The modeled fires originated from point sources in the morning hours.

Fire environment modeling data used

	low	medium	high (extrem)
1 hour dead fuel moisture (%)	9	6	3
10 hour dead fuel moisture. (%)	10	78	4
100 hour dead fuel moisture (%)	11	8	5
living heraceus fuel moisture %)	150	120	70
wind speed (m/s)	3	10	20

In addition to the extreme values for these fire spread parameters, we also examined the fire spread values under low and medium fire spread conditions. This allowed us to assess in which cases only surface fire develops in each stand type, when we should expect passive and when active crown fire.

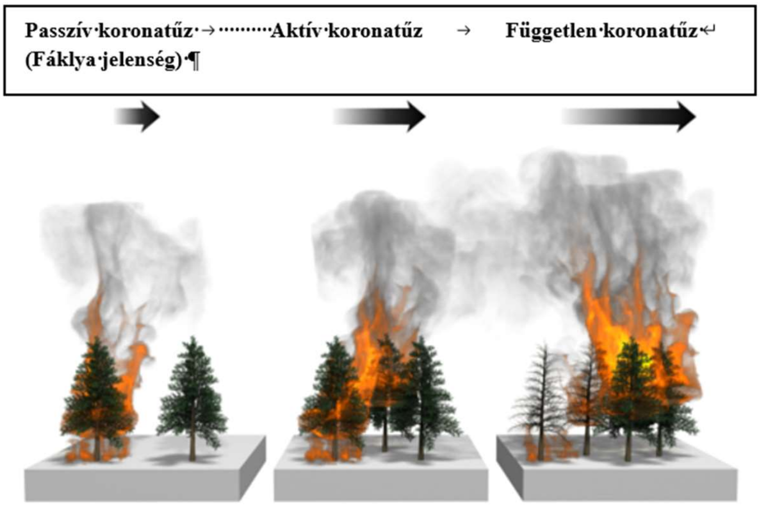

Figure 8. Types of crown fire

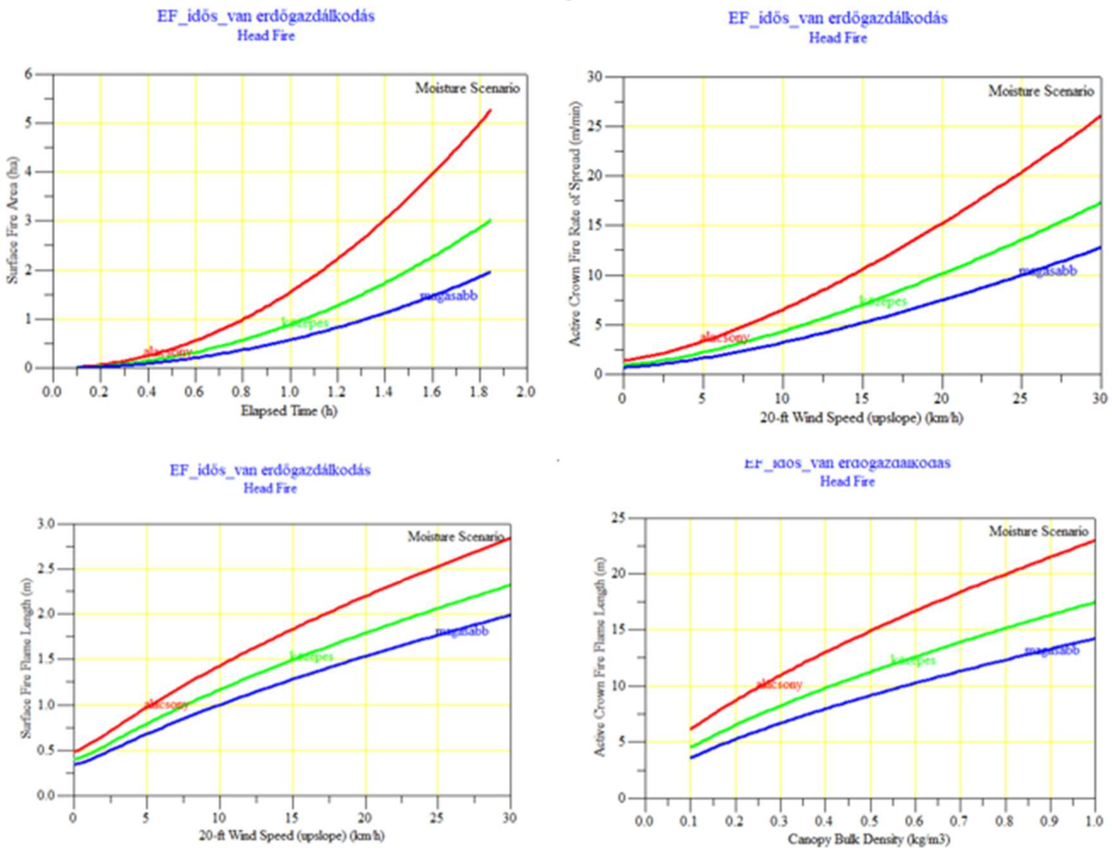

Figure 9. Modeling result sample for EF stocks

Technical parameters of fire barriers

In the current support system, which is represented by the call for proposals with the code number KAP-RD41-1-24 entitled Prevention of biotic and abiotic damage threatening the forest potential, applications can be made for fire barriers of types A, B and C. The type A barrier is 2 m wide and can be placed on the outer perimeter of the forest and is suitable for stopping and slowing down low-intensity vegetation fires. The type B so-called walkable barrier is 4 m wide, which is suitable for stopping low-intensity surface forest fires and for the march of units participating in firefighting. The type C barrier is 10 m wide, of which at least 4 m is a soil surface kept clean of undergrowth, twigs, shrubs and trees, disced, ground-milled, ploughed or graded, smoothed, biomass-free, to which a strip of at least 3-3 meters wide of crushed stems, free of trees and shrubs belongs on both sides. Unfortunately, in the current call for proposals, despite the significant technical difference, type B and type C pastes receive the same amount of support, therefore, practically no type C paste is produced. However, it should be noted that type C paste is not suitable for suppressing intensive surface forest fires and crown fires.

Technical parameters of type D wide fire pastes

The fire spread modeling was performed in 5 different biomass models, but standardization of the pastes to be developed is necessary from a forestry planning, support policy, and licensing perspective.

At lower fire spread risk, we had to count on surface fire in all biomass models. Under medium fire spread conditions, the model showed active crown fire in all cases in the case of stands of the same age, while in the case of stands of different ages or mixed with lower closure, we encountered passive crown fire in 70 percent of cases. Under extreme fire spread conditions, crown fire occurred in all biomass models.

In the case of medium fire spread conditions, the flame length of the developing crown fire is between 15 and 22 m, depending on the stand structure. In the case of extreme fire spread conditions, the flame length can reach 40-50 m. In our opinion, it is not worth sizing a wide fire barrier for extreme fire spread conditions, since in such cases the spread of a forest fire is typically accompanied by unstable atmospheric conditions, which results in a significant potential for wildfires. In other words, even if the fire front can be stopped with a 70-100 m wide fire barrier, it will not be possible to manage wildfires. Therefore, from both an ecological and economic point of view, it is worth optimizing the technical parameters of wide fire barriers for medium fire spread conditions, which means a 20 m wide fire barrier. This is suitable for stopping the fire head (downwind side) of a forest fire spreading in moderate fire spread conditions, and for effectively managing the fire back (upwind side) and fire wings even in extreme conditions. A 4 m wide strip of the 20 m wide fire strip must be completely biomass-free and passable! This can be a paved road opened to public traffic, a properly designed private forest road, or a built approach trail. From a forestry legal perspective, it must be noted that a fire strip wider than 6 m is considered an area serving forestry activities and does not form part of the forest. In the case of the creation of such a fire strip, the compensation options of the forest manager must be examined, since the wide fire strip serves to protect large areas of forests, which is why he cannot suffer any financial disadvantage.

Creating a traditional firebreak that is 20 m wider would cause significant financial losses to forestry, as one hectare of productive area is lost for every five hundred meters, which, based on a 30-40-year-old pine cutting cycle, is a loss of 5-7 cubic meters of growth per hectare per year.

In addition, firebreaks that are too wide also increase the risk of invasive species settling. If necessary, the traditional wide firebreak can be supplemented with green firebreaks, or with stand training interventions or restructuring. By using these methods in combination, it is possible to ensure that the protection lines created in this way provide adequate protection even under extreme fire spread conditions, since the actual width reaches or even exceeds 50-70 meters.

However, there are natural linear facilities that, due to their function, may be suitable for creating a wide firebreak, without causing any economic loss. These areas are the openings that serve to place medium or high voltage electric power lines or gas pipelines. In these cases, the safety distance from the lines can reach up to 30-40 m. It is by no means possible to maintain large tree stands within the safety distance, so they are excellently suited for wide firebreaks. In the case of particularly connected high-risk forest stands, the creation of a wide firebreak can also serve to create a safety zone, where the equipment and people involved in extinguishing can be evacuated in the event of extreme weather conditions. In the case of such a function, however, the width of individual sections of the wide firebreak must reach, or even exceed, the flame length calculated for the given forest stand, i.e. 50 meters.

Technical parameters of type D green firebreaks

The essence of the design of green firebreaks is to create stand conditions in which surface fire or at most passive crown fire can be expected to develop even under moderate and extreme fire spread conditions. We can achieve this by modifying the biomass conditions that fundamentally influence the fire spread conditions, since we have no influence on the weather and topography within the framework of forest management. Modification of biomass conditions can take place in the short and medium term. The former group includes the transformations of stand conditions through logging, and the latter group includes structural transformations when the spread of fire in the horizontal direction is slowed down and the vertical development into a crown fire is prevented by using deciduous tree species or a wider planting network.

After end use, when reforestation

If a high fire risk stand is used, if the site type variant of the given forest section allows it, the forest must be reforested with deciduous species. In the Bugac District, these species can be acacia and grey poplar, the former if the nature conservation status of the area allows it. Private forest managers prefer acacia if possible, but from a professional point of view, the two tree species can also be combined. On the one hand, acacia improves the site conditions by fixing nitrogen, and on the other hand, both species can be regenerated from shoots during the next cutting round, so the area does not need to be stumped. However, in both the Bugac and Jakabszállás forest blocks, and indeed in the entire forest planning district, the site type variant of medium-deep humus sand, independent of the effect of excess water, is primarily characteristic, which only allows restructuring with deciduous species to a limited extent. This is especially possible if the micro-topography also facilitates it.

However, based on our studies, it is also possible in less favorable growing areas to reforest with 3 or 4 rows of deciduous species next to the clearings, if necessary by supporting the deciduous species with higher quality propagation material or by periodic irrigation in dry weather. With this intervention, a green fire patch is created on the side of the 4 m wide clearing affected by forest regeneration, taking into account the traditional 2.5 m row spacing. In this area, any crown fire that may develop will develop into a surface fire.

In the case of cuts

In the case of non-end-use stands, the formation of a green fire patch can be combined with reducing the upper crown level closure of the main tree species and reducing the amount of surface biomass. In each stand type, a 30, 40, 50 percent closure reduction must be carried out and the lower canopy level and the shrub level must be removed. Thus, the crown fire can turn into a surface fire. For the purpose of the closure reduction zone, it is worth carrying out deciduous underplanting in order to prepare for the end use. In both black pine and Scots pine stands, gray poplar is, in our opinion, a suitable tree species for this. The width of the canopy affected by the closure reduction must reach one and a half times the height of the stand.

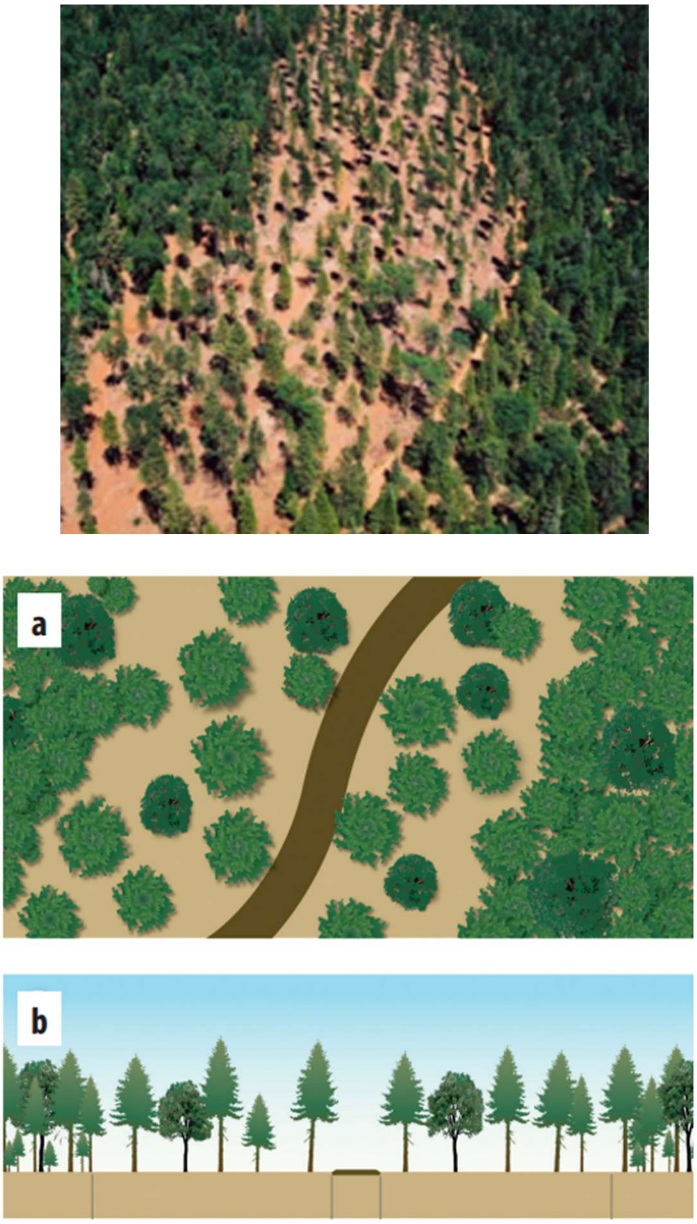

Figure 10. Fuel break

Experimental interventions

The experimental interventions were carried out in connection with the biomass survey. During the experimental interventions, different degrees of closure reduction were achieved in the sample plots. Deciduous tree rows were also implemented in forest regeneration sample areas. The experimental establishment of the wide firebreak took place in a high-risk oak forest plantation of more than 100 hectares in Nagylóc.

Cost calculations

The cost calculations were carried out for EF, FF, EF-FF, Lombelegyes EF and FF stands and juniper summer stands in such a way that they can also be used on a unit cost basis for Kap subsidies. It should be emphasized that the current subsidy system applies to firebreak maintenance and does not take into account establishment costs. For maintenance and end-use related green firebreaks, the unit cost proportional to the length of the firebreak can be used, but for maintenance cuts, the unit cost proportional to the cubic meter harvested and the biomass removed is appropriate.

Trail plans

The trails were defined in shape format as separate wide firebreak and green firebreak overlays. The green firebreak intervention type was also displayed in the trail attributes. The areas without forest managers were also indicated in the trail.