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Increase Efficiency in Extinguishing Wildland Fires with Light Forest Fire Trucks

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Short report

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Abstract

Climate change is affecting all countries of the world. An increase in temperature and a decrease in the moisture content of the vegetation cause an increase in the burning rate of fires. To fight wildland fires at least as effectively in the future as we do today, we need vehicles. This article explores effective tools for this. By researching the relevant literature, drawing logical conclusions, and performing simple mathematical calculations, the author determines what are the most important features, also known as firefighting tactics, that are required to design a light forest firefighter that is optimal for forest firefighting. The result of the research is a light forest fire truck capable of carrying 6 firefighters and transporting at least 1000 liters of water in difficult terrain. By using a light forest fire truck, the physical size and weight can also be reduced while the average speed increases.

Keywords: Climate change; efficiency; light fire truck; wildfire

1 Introduction

Climate change, and the warming that comes with it, is a current problem that we can only very little influence in the light of our current experience, but it will present us with challenges in the foreseeable future that we must be prepared for today. If the climate in Central Europe changes according to the current trend, and this increases the average annual temperature, it will necessarily lead to an increase in the duration of periods of increased forest fire risk. In addition, a possible vegetation fire will be more intense, within decades even more intense than any domestic forest and vegetation fire so far. This is supported by the figure below, which clearly favours the development of more frequent and intense fires (Bodnár, Bérczi, 2018; Debrecenweet al., 2017; Pántya, 2018)

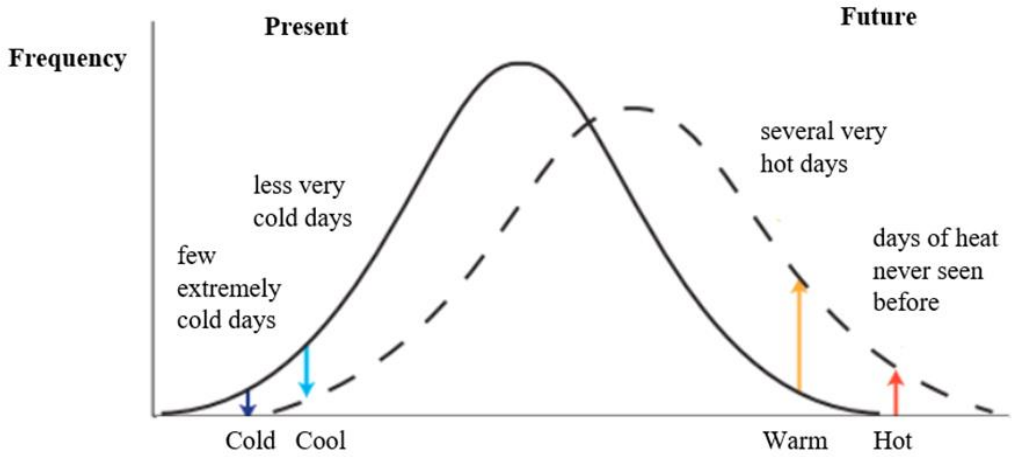

Fig. 1 Mean temperature change and frequency and their effects

Not only does the table predicts days of unprecedented heat, but we can see that the frequency of currently high record high temperatures can be many times higher than before. In addition, the expected amount of precipitation will not change significantly, but the number of precipitations with light and moderate precipitation will decrease on average, while heavy rainfall will be more frequent. As a result, the moisture content of the vegetation will be lower and thus the risk of fire will increase significantly, in addition, it is likely that the intensity of the burning itself will be higher, which means a higher rate of spread (Pántya, 2016; Nagy, 2004).

The motivation of the research is the legitimate demand of society to carry out firefighting tasks at least as efficiently in the coming years as we do now. It logically follows that we need improvement. The tools and procedures needed for a successful intervention need to be developed today. This is also important to enable interveners to carry out their work with the least possible physical strain.

The objectives of the author are:

- determine the increase in fire intensity, the size of the area affected by the fire, in a specific case.
- To establish that by using a vehicle with a higher average speed and a smaller size, it is possible to start extinguishing a more intense fire under similar conditions as in the current conditions.
- Identify the vehicle from which the light forest fire truck can be constructed.

2 Material and Methods

At the time of writing, we have collected the relevant characteristics of vehicles currently used in forest fire extinguishing. Based on my own professional experience and logical conclusions, we have selected the properties that make a vehicle suitable for transporting water and firefighters as close to the fire as possible. We simulated a theoretical fire propagation using simple mathematical calculations to determine how the extent of the fire changes when we arrive with a light forest fire truck instead of a medium-weight fire truck.

Damage caused by an outdoor fire increases in proportion to the total duration of the fire. In Central Europe, thousands of outdoor firefighters successfully extinguish each year. Based on this, we can see that with the current technical background, the training of the staff, and the physical condition, the current tasks can be solved. Over the years and decades, the topographic conditions will not change significantly, nor will the density of the road network. We assume that the number of intervening fire-fighting units will not decrease in the future either. If we accept these conditions, we can conclude that it will take a similar amount of time to arrive at the scene of the damage as at present (Rácz, 2018; Rádi, 2016).

Let us see what differences we can experience at the same time of arrival if we must extinguish a fire under similar conditions but more intensely. We want to illustrate the problem with a specific example.

We used simple mathematical calculations for the calculations. We based it on a theoretical fire propagation, according to which fire spreads at a constant rate in all directions under unchanged meteorological conditions (Teie, 2018).

$$R_{fire} = t_{all} * v \quad (1)$$

$$K_{fire} = 2 * R_{fire} * \pi \quad (2)$$

$$A_{fire} = R_{fire}^2 * \pi \quad (3)$$

Low intensity of fire (nowadays)

We calculated with an average fire spread nowadays, this is 2 \frac{m}{min}. The fire squad is alarmed 10 minutes after the fire inflammation. The duration of the approach to the fire was determined to be 40 minutes due to the varied road conditions. Using equations (1), (2), and (3), we determined the parameters of the fire at the time of arrival (Teie, 2018; Restás et al., 2015).

$$R_{fire} = 50\ min * 2\ \frac{m}{min} = 100\ m$$

$$K_{fire} = 2 * 100\ m * \pi = 628{,}4\ m$$

$$A_{fire} = 100^2 * \pi = 31400\ m^2$$

Even in a relatively low intensity fire, firefighters face a sizeable fire front.

Medium intensity (future, more intense fire)

When analysing the much larger temperature data, it is difficult to determine exactly how much more intense the combustion will be, but a spread rate of one and a half times seems realistic to me.

In this case, the rate of fire spread is 3 $\frac{m}{min}$. As in the previous case, the fire brigade will be alerted 10 minutes after inflammation. The road conditions are the same, so the duration of the approach is the same, a total of 40 minutes. Using equations (1), (2), and (3), we can determine how much the parameters of the fire have changed (Teie, 2018).

$$R_{fire} = 50\ min * 3\ \frac{m}{min} = 150\ m$$

$$K_{fire} = 2 * 150\ m * \pi = 942\ m$$

$$A_{fire} = 150\ m^2 * \pi = 70650\ m^2$$

In this case, a much larger fire front is obtained, and while the circumference of the fire increases in direct proportion to the intensity of the burn, the size of the area already burned exponentially. This is a condition experienced on arrival at the scene of a fire, and firefighting only begins after that.

So, if we have to extinguish a more intense fire in the same area, we will obviously have to deal with more damage, of course, assuming that the effectiveness of the extinguishing is similar to the current one. In my opinion, the period of free spread of fire should be reduced to the shortest possible time, which is easier to do than trying to reduce the size of the burned area (and thus the damage value) only with the efficiency of firefighting.

This can be solved by using vehicles that travel at a higher average speed than at present, and whose physical dimensions and weight are less than those of the fire trucks currently in use, making it less likely that a pedestrian approach will be required (Teie, 2018; Restás et al., 2015).

Design of a light forest fire truck

Extinguishing outdoor fires is often a logistical problem. The right forces need to be delivered to the right place as soon as possible. The problem arises right here, the off-road capability of the mid-weight fire trucks currently used in the largest numbers does not allow interveners to be transported right next to the fire. This is mostly a protracted pedestrian approach, and dirt roads also run at low speeds (Zsitnyányi, 2020).

Tab. 1 Parameters of different fire engines

Type	Crew (person)	Amount of water (m^3)	Weight (t)	Wide x high (cm)	Average speed on dirt road (km/h)
Rába R16	6	4	16	2500 x 3380	20
Unimog U500	3	2,7	16	2500 x 3500	20
Vw Amarok	4	0,12	2,5	2000 x 1700	40
Light Truck	6	1	3,5	2400 x 1800	40

The solution is a vehicle that can reach higher speeds than it does on the dirt road and can also travel in terrain where current vehicles no longer do. In addition, its small weight and size do not hinder the narrow forest, mountain roads. Most Pick-Ups meet these criteria. Among these vehicles are those that can carry up to 6 people and can carry up to 1,000 l of water. Dodge RAM meets these parameters.

While the average travel speed of medium-weight fire engines is set at 60 km/h by fire-safety plans, in practice it drops to just 20 km/h when driving on dirt roads. Leaving the dirt road is often unsafe, off-road the structure, weight and center of gravity of the vehicle do not allow driving, so a pedestrian approach is required, which is about 4 km/h.

Smaller Pick-Ups outperform this, easily reaching 70 km/h. They are also capable of an average speed of at least 40 km/h on dirt roads and a speed of at least 10 km/h on off-road.

To find out whether these speed differences represent a significant difference in practical use, we performed a calculation in which the assumed fire is located 15 km from the fire department. This must be overcome by 10 km of asphalt road, 4 km of dirt road, and 1 km of terrain (Zsitnyányi, 2020).

The results obtained are summarized in a table.

Tab. 2 Average speed on the different quality of road

Type, and lenght of road	Mid-weight fire truck (min)	Light fire truck (min)
Asphalt road 10 km	10	8
Dirt road 4 km	12	6
Off-road 1 km	15	6
Summarise	37	20

The difference is significant, it would only change if the fire was located very close to the fire department and could be approached along good quality roads. However, we know from experience that these conditions rarely occur in the case of forest and vegetation fires.

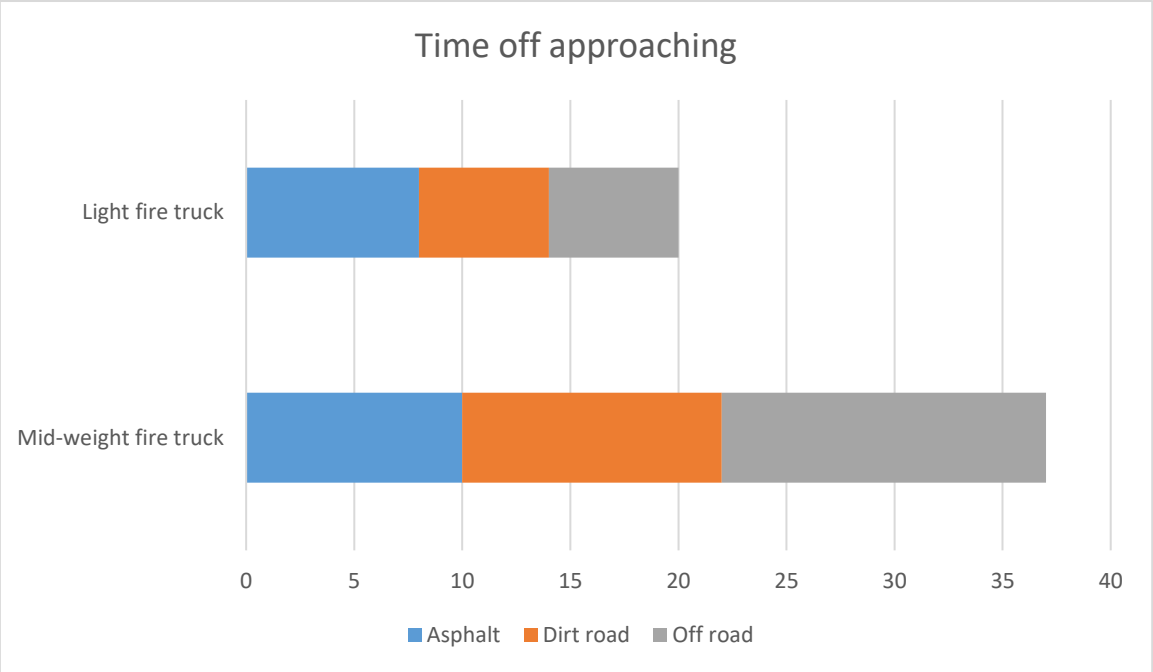

Fig. 2 Time of approachig on different quality of roads

3 Results and Discussion

The question is whether the advantage of a light off-road vehicle traveling at a higher average speed is sufficient to do not have to start extinguishing a fire in a more unfavourable situation than at present in the event of more intense fires. This is a condition that the burned area and the damage caused should not be greater than at a lower rate of fire spread, so that the subsequent firefighting can be at least as economically efficient as it is today.

The lower fire speed of 2 m/min and the longer total fire time of 50 minutes in the case of free fire spread approaching medium-mass fire engines approached, with a fire circumference of 628 m and an area of 31,400 m^2.

By calculating a fire speed that is one and a half times more intense, we can examine whether the area affected by the fire at the time of arrival can be reduced to at least 2 m/min, or possibly below, by using Pick UP, thus reducing the time of arrival.

Using equations (1), (2) and (3) again, but already considering the shorter arrival time, which is 20 minutes, it is possible to calculate how large the parameters of the fire will be at the intensity of 3 m / min, and the described 15 within a kilometer distance.

$$R_{fire} = 30\ p * 3\ \frac{m}{p} = 90\ m$$

$$K_{fire} = 2 * 90\ m * \pi = 565\ m$$

$$A_{fire} = 90\ m^2 * \pi = 25434\ m^2$$

Fig. 3 Light Forest Fire Truck

We can see that as the exit time shortens, the area affected by the fire is significantly reduced. This means that tactically in this case, the unit arriving with the Pickup will not start at a disadvantage, despite the more intense spread of fire. This can be a solution to the problem, and even the elimination of the damage can be started from a more favourable situation in case water extinguishing is used.

However, it is worth noting that the cost of purchasing and operating a light forest fire Truck is significantly lower than that of larger Fire Trucks. However, it has significant benefits in extinguishing outdoor fires (Restás, 2020; Zsitnyányi, 2020).

Optimized forest fire truck

Based on the values obtained and my practical experience, we try to determine what conditions a forest fire vehicle should meet. In the absence of suitable off-road vehicles, the lengthy pedestrian approach favours the free spread of fire. Upon arrival at the fire, the area of the fire is not immediately visible due to the articulation of the terrain, so reconnaissance may be delayed until the fire chief is satisfied of the true area of the fire. Only then can you determine the forces and tools needed to put out the fire. Again, this only favours the spread of fire.

Intervention is most often hampered by the fact that we cannot approach the fire with the water tender so much that we can use the quick-acting beams and must approach them on foot. The solution to this is a vehicle with adequate off-road capability, which is suitable for transporting 6 firefighters, is suitable for transport on narrow, mountain roads due to its size, and can transport the necessary professional equipment as well as extinguishing water (NFPA 1977; Zsitnyányi, 2020).

Fig. 4 Dodge RAM fire engine

Examining the properties of several types, we found the Dodge Ram Tradesman to be the most suitable vehicle for the purpose. Its unique feature is that it can carry 6 people in two rows of 3 people.

Its height is between 1800 and 1900 mm depending on the design (this also depends on the size of the rim or tire), it is much lower than any forest fire truck used so far, therefore its center of gravity is low. However, depending on the body, its load capacity is approximately 1850 kg. This capacity allows the vehicle to carry equipment used to extinguish forest and vegetation fires, and a full swarm of dimensions, and off-road capability to transport the unit as close as possible to the fire. In my opinion, such a vehicle would be a great tool to use with a high-pressure extinguisher and special equipment for extinguishing forest fires. Due to its load capacity, it would be able to deliver up to 1000 l of extinguishing water in addition to professional equipment.

The disadvantages of the Volkswagen Amarok fire trucks currently in service are the low number of crew and the low transportable weight. In my experience, a crew of four and only 120 l of extinguishing water are not enough to put out intense fires. The basic unit of the fire force is the squad. If a start must be split to be transported by a light vehicle, the distribution of forces is complicated and time consuming. The amount of water supplied is sufficient for less than 3 minutes of continuous operation, considering the nozzle output of 40 l per minute. Even an ATV would be able to carry this amount of water, at a lower cost, and even on more difficult terrain (Zsitnyányi, 2020; NFPA 1977; Restás, 2020).

Fig. 5 Fire fighting with ATV

With what has been described, we wanted to illustrate that a small fire truck can be used in many ways and can make the intervention fire units more mobile. But the condition for this is that the swarm comes to the fire with the light forest agent and delivers the right amount of water. The solution is not to keep light forest fire trucks in service as a special fire truck, but to have the opportunity to decide, based on the professional experience and local knowledge of the fire squad leader, to go to the open fire with a light forest agent instead of a universal fire truck.

Firefighters could respond quickly to changed conditions when using a vehicle like this, and quick redeployments could be resolved. They could get as close to the fire as possible, shortening the otherwise lengthy pedestrian approach and thus the phase of free spread of the fire. Such light-weight fire engines are used in many countries, including the poorest regions of Africa, because of their advantageous properties and simplicity, as well as affordable goods.

If a light forest fire truck with 1000 gallons of water is equipped with the necessary hand tools, you can extinguish a fire much more effectively than a mid-range fire truck (Zsitnyányi, 2020; NFPA 1977; Restás, 2020).

Fig. 6 Portable Bush Fire Unit

Many companies specialize in the manufacture of fire-fighting equipment that can be operated from simple IBCs. These are universal devices, installed on site, or even mounted on a platform, with a hose length of up to 100m. Equipped with an ultra-high-pressure pump, it allows water-saving firefighting and is easy to handle due to its small diameter, lightweight fire hose. The weight of such a device in the case of an empty tank is only 65 kg, so it can even be manually lifted or removed from the vehicle if the intervention requires it. This may be necessary if citizens or even fire forces must be evacuated from the area affected by the fire. Fortunately, such situations are rare in Central Europe, but not unprecedented, and may become more frequent as the intensity of fires increases (Zsitnyányi, 2020; NFPA 1977; Restás, 2020).

Indirect approach and post-firefighting work also make good use of light vehicles, these activities can be performed effectively on the front line of the area closely affected by the fire, so a firefighting vehicle capable of approaching any point in the terrain is required, medium mass fire trucks are rarely suitable (Teknős, 2018).

Fig. 7 Indirect approach

4 Conclusions

Climate change is affecting all countries of the world. An increase in temperature and a decrease in the moisture content of the vegetation cause an increase in the burning rate of fires. To tackle outdoor fires at least as effectively in the future as we do today, we need new tools and new solutions.

Extinguishing outdoor fires can be done more effectively by looking at the features of a fire truck that can be used to start extinguishing a fire sooner. One of the most critical properties is the maximum average speed available, but not on an asphalt road, but over the entire distance. We can significantly

increase this if we can leave the asphalt road, drive on dirt roads and then in difficult off-road conditions, and transport at least 1000 l of water next to a firefighting squad

My calculations proved that even with increasing fire intensity, we can start firefighting under conditions like the current one. Another advantage is that if there is no need for a pedestrian approach, the fire water and equipment are located next to the fire, this again allows for time-saving tactical solutions, which further increases efficiency.

By using a light forest fire truck, the physical size and weight can also be reduced while the average speed increases. In addition, the cost of purchasing and maintaining a light vehicle is significantly lower than that of a heavier mass fire truck. This means that more could be obtained from a light vehicle, and not only fire departments but also forestry and volunteer fire departments could be equipped.

Extinguishing outdoor fires is primarily a logistical problem: the right forces need to be delivered to the right place and at the right time, which is the key to success. We therefore see the future of outdoor firefighting not in the use of heavy-weight, high-volume fire-fighting fire trucks, but in fast-moving, well-equipped, large-scale interventions that can reach most points in the firefighting area and respond quickly to changing conditions.

Finally, we look back at the objectives.

- As the intensity of the fire spreads, the area affected by the fire increases significantly. It follows that there is a need to increase efficiency.
- With a significant reduction in approach time, the dimensions of the fire on arrival were smaller than they were in the case of a less intense fire. This can be achieved by using a vehicle that has a higher average speed and smaller physical dimensions.
- We examined the properties of several vehicles and found that the Dodge Ram can carry a squad of 6 firefighters and 1000 l of water. These features make it suitable for being the optimal fire truck for forest firefighting.

Based on the obtained results, we conclude that the light forest fire truck with the characteristics we have defined is suitable for solving our challenges in the coming decades.

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