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Review Paper

A LITERATURE REVIEW OF KEY FINDINGS IN FUNDAMENTAL FOREST FIRE RESEARCH

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Abstract. *The purpose of this review is to examine key findings in the fundamental research of wildfire flammability characteristics. The review begins with a brief introduction, highlighting the growing need for more detailed research into the development of forest fires due to increasingly pronounced climate changes. This is followed by an overview of the application of devices operating on the principle of calorimetry, emphasizing additional possibilities for setting and adjusting these devices. Upon reviewing the literature, it becomes evident that the majority of research on the flammability of forest vegetation is primarily focused on the moisture content levels in fuels. For this reason, the third part of this paper is dedicated to exploring the influence of moisture content on the flammability of forest vegetation. Towards the end, an overview of the types and possibilities of igniting forest fuel is provided, with a particular emphasis on the creation of firebrands as a source of ignition for vegetative fuel.*

Key words: *forest fire, calorimetry, moisture content, ignition types.*

1. INTRODUCTION

With a warmer and drier climate projected for the future, the intensity and frequency of forest fires are expected to worsen. This escalation will pose an even greater threat to forestry, agriculture, and human well-being [1].

The term "wildfire behavior triangle" as found in the literature, explains that wildland fire behavior is influenced by three key factors: fuels, weather, and topography. Fuels can be categorized into two natural levels of organization: fuel particles and fuel beds. Fuel particles are associated with varying sizes, shapes, moisture content, and etc. While fuel beds are collections of fuel particles, and they are characterized by factors such as fuel quantity (loading), depth, compactness, and continuity. Additionally, vegetation attributes

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such as fuel structure, spatial arrangement, moisture content, chemical composition, and the proportion of dead and live fuel varies during the year. Weather parameters, including precipitation, solar radiation, wind speed and direction, air temperature, and humidity, influence wildfire behavior. Topography directly influences fire behavior through slope steepness and indirectly through interactions with other environmental factors. [2].

Researchers investigating the flammability characteristics of forest vegetation have individually considered all previously mentioned factors, conducting numerous correlation analyses between flammability parameters and fuel traits to enhance understanding of the dynamics and spread of forest fires. To perform the aforementioned analyses, numerous devices were employed and developed. In [3], authors review 134 studies on tissue-level flammability, emphasizing the methods employed. The most common methods identified include the epiradiator chamber, muffle furnaces, wind tunnels, and direct flame approaches.

In [4], the authors underscore the significance of comprehending litter flammability in predicting fire behavior and understanding ecological impacts in fire-prone ecosystems. Additionally, they evaluate the needs and challenges of scaling up laboratory findings to field observations of fire behavior.

The purpose of this work is to review key findings from scientific literature, emphasizing properties most frequently associated with exploring the flammability of forest vegetation.

2. CHARACTERIZING FOREST FUEL FLAMMABILITY THROUGH CALORIMETRIC ANALYSIS

The heat of combustion represents the energy released during the complete combustion of a unit mass of fuel in a pure oxygen atmosphere. In theory, the heat of combustion can be calculated by understanding the energies of reactants and products, as derived from the chemical reaction. However, due to the imperfect stoichiometric conditions during combustion in wildland fires, predicting the exact formation of combustion products becomes challenging. Therefore, a more precise and reliable approach is to measure the heat of combustion, rather than relying solely on theoretical calculations [2]. The standardized method for measuring the heat of combustion is defined by ASTM D 5865 (Test method for gross calorific value of coal and coke), which employs the oxygen bomb calorimeter.

In [5], the authors explore the relationship between flammability characteristics and species within the same genus. The researchers utilized an oxygen calorimeter to determine the energy content of plant samples based on their dry weight. This instrument measures the combustible quantity of the sample and calculates the energy released during combustion. In [6], the authors suggest that assessing flammability in an oxygen bomb calorimeter may have limitations in capturing certain aspects, especially those associated with physical processes and physiological changes in plant parts. Results obtained from an oxygen bomb calorimeter might not fully capture the significance of gas diffusion through the fuel during a rapid flaming phase, a critical factor in determining flammability.

Unlike oxygen bomb calorimeter tests where fuels are fully consumed, wildland fuels are never completely burned in fires. This discrepancy can lead to measurements indicating higher heat of combustion than what occurs in reality during wildland fires [7]. In their study, Della Rocca et al. (2015) employed various devices for a comprehensive characterization of flammability, considering different aspects such as ignitability, sustainability, combustibility, and heat release rate. The oxygen bomb calorimeter was utilized to measure the gross heat of combustion, offering additional insights into the flammability of the samples. The heat content of the analyzed samples was consistently higher in the oxygen bomb tests compared to the mass loss calorimeter tests [8], aligning with the statements in [7]. Additionally, the results in [9] show that the effective heat of combustion is between 18% and 44% lower than the gross heat of combustion.

Unlike results obtained from a bomb calorimeter, more realistic values can be derived from various standardized testing techniques, particularly those based on the principles of calorimetry [10]. Devices like the cone calorimeter (CC), fire propagation apparatus (FPA), and mass loss calorimeter (MLC) enable the measurement of heat of combustion for incomplete combustion, considering char formation.

In addition to measuring the temperature and geometry of flames, a common goal in fire science is to quantify the size of a fire by assessing the heat release rate (HRR) [11]. The calculation of HRR during combustion depends on the employed devices. It can be determined by measuring combustion products such as CO and CO2 in an exhaust duct, a method related to the FPA. Alternatively, oxygen sensors can be used to measure the amount of oxygen consumed during combustion to determine the HRR, as is the case with the CC. Regarding the MLC, the HRR value can be determined by measuring the temperature of the products formed during combustion.

The results obtained from these devices can be utilized to describe the components of the flammability of forest vegetation, as stated in [12], [13]:

- Ignitability - the ignitability of the sample is determined by recording the time for sustained ignition;
- Sustainability - the sustainability of a fire depends on the ignition characteristics of the fuel and the total heat released during the combustion of the fuel;
- Combustibility – the combustibility reflects the speed at which a fire burns and can be expressed through the heat release rate;
- Consumability – the consumability provides information on the extent to which the fuel is consumed, measured through the residual mass fraction.

For small bench-scale devices based on the calorimetry principle, the recommended sample size is 10 x 10 cm to ensure uniform incident radiant heat flux onto the specimen surface [14]. These devices are equipped with load cells that can be used to measure the mass loss rate while the samples are burning. Moreover, the FPA possesses the capability to control the airflow through the sample. Depending on the volume of the sample holder, the fuel mass may vary. Consequently, different bulk densities can be produced, influencing the burning behavior. In study [15], the FPA was used to examine the effects of transport in the fuel beds by controlling the airflow, and analyze variables such as time to ignition, duration of flaming combustion, and peak heat release rate for two species of pine needles. For the first time in calorimetric studies, the authors introduce a custom-made sample holder. These holders are employed to systematically study the porous properties of fuel beds, enhancing understanding of the effects of airflow transport within the fuel beds, and assessing the flammability characteristics of forest fuels [15]. These approaches represent new trends in investigating the flammability characteristics of forest vegetation using calorimetric devices.

In their study, Bartoli et al. (2011) explore the role of surface-to-volume ratio, fuel packing ratios, and chemical properties in the burning dynamics of pine needles using the FPA. They observe that increasing the flow magnitude can result in a delay in burning and induce a cooling effect on combustion. [16]. Besides surface-to-volume ratio, factors such as fuel packing ratios, chemical properties, flow conditions, fuel species particularities, and their interactions contribute to the governing of burning dynamics. The sample holder design allowed for the examination of internal porous fuel bed characteristics and their interaction with flow conditions and fuel species properties, contributing to a better understanding of the factors governing burning dynamics.

Santoni et al. (2015) conducted a study on the scale effects and experimental setups concerning heat release rate, smoke production rate, and species yields during the burning of a vegetation bed. They investigated the burning of a vegetation bed using both the cone calorimeter and the furniture calorimeter on small and large scales. This work represents an initial effort to highlight the scale effect and the influence of combustion setups on flammability parameters. The study concludes that results obtained at the bench scale cannot be directly extrapolated to the full scale, even for litter with a high packing ratio [17].

Unlike CC and FPA devices, the mass loss calorimeter (MLC) device offers an alternative approach to measuring heat release. From the obtained results in [18], the authors demonstrated that the MLC device exhibits good repeatability and provides a reasonable approximation to the heat release rate (HRR) values obtained with a cone calorimeter. The MLC device allows for the evaluation of forest fuel flammability and combustion properties.

The study in [6] focuses on evaluating the flammability of gorse (*Ulex europaeus L.*) plant parts and whole plants after prescribed burning. The aim is to understand the changes in flammability over time, utilizing both full-scale methods such as an outdoor wind tunnel and epiradiator with a flaming firebrand as the point ignition source, and bench-scale devices like a mass loss calorimeter with a porous holder. The results indicate that ignitability is highly dependent on the type of ignition source, while combustibility is more influenced by the dead fraction of the plant.

Melnik et al. (2022) introduced a novel method that assesses flammability by quantifying the fuel's net contribution to the energy release of the incoming flame, employing in-flame flammability testing. This method utilizes oxygen consumption calorimetry to gauge the energy release contribution of live fuel to the methane flame in comparison to the methane flame alone. The energy release contribution of live fuel is determined as the difference in energy release between the methane flame interacting with live fuel and the methane flame in isolation. In-flame testing results in fuel ignition and consumption similar to those observed in wildfires, rendering it a realistic approach for measuring flammability [19].

To determine the flaming ignition time of samples, one criterion is the ignition temperature. However, the ignition temperature can vary due to conditions and testing methods applied. For instance, the ignition temperature for wood can range between 296 and 497 °C [20]. In this context, it is more practical to conduct flammability tests with fixed parameters, such as heat flux.

An important feature of devices based on the calorimetry principle is their ability to establish burning conditions with a fixed heat flux value. Heat flux is defined as the amount of energy transferred to a sample per unit area and typically has units of kW/m^2 in fire applications. The heat flux from the fire to the surface includes contributions from both radiation and convection [21]. In calorimetry principle devices, heat flux is measured by water-cooled gauges, commonly including Schmidt-Boelter type. The Schmidt-Boelter gauge, utilizing a thermopile-style design, measures temperature at various locations across a substrate. Due to its ability to measure heat flux accurately in environments with both radiation and convection, it is considered more accurate device for assessing heat transfer in fire environments [21].

Table 1 summarizes the most cited authors whose experiments involve the application of bench-scale devices for analyzing the flammability of forest vegetation. The table is formed based on the following criteria: apparatus used, applied heat flux, analyzed samples, and type of sample holder.

Table 1 A review of research on the flammability characteristics of forest vegetation using bench-scale devices based on the calorimetry principle

Authors	Apparatus	Heat flux $[kw/m^2]$	Samples	Sample holder type
Schemel et al. (2008) [15]	Fire propagation apparatus	-	Pine needles	Circular porous (0%, 26% and 63% opening)
Bartoli et al. (2011) [16]	Fire propagation apparatus	25	Pine needles	Circular porous (0%, 26% and 63% opening)
Simeoni et al. (2012) [22]	Fire propagation apparatus	8.5 - 60	Pine needles	Circular porous (26% and 63% opening)
Lamorlette et al. (2015) [23]	Fire propagation apparatus	8 - 55	Pine needles	Basket (0% opening)
Jervis et al. (2016) [24]	Fire propagation apparatus	50	Pine needles	Circular porous (63% opening)
Weise et al. (2005) [25]	Cone calorimeter Intermediate-scale calorimeter	25 -	Ornamental vegetation (foliage and branches)	Square 100x100 mm -
Blank et al. (2006) [26]	Cone calorimeter	30	Grass - cheatgrass	Square 100x100 mm
Dibble et al. (2007) [27]	Cone calorimeter	25	Invasive and non-invasive species (different growth forms)	Square 100x100 mm
Santoni et al. (2015) [17]	Cone calorimeter Furniture calorimeter	-	Pine needles	Circular porous (99% opening)
Fateh et al. (2016) [28]	Cone calorimeter	10 - 50	Pine needles	Basket (0% opening)
Madrigal et al. (2009) [18]	Mass loss calorimeter	50	Pine needles Twigs and leaves Moss	Square porous (63% opening)
Madrigal et al. (2011) [9]	Mass loss calorimeter	50	26 forest fuels (stalks, leaves, twigs, needles)	Square porous (63% opening)
Fernandez-Gomez et al. (2011) [29]	Mass loss calorimeter	50	Pine needles Twigs with leaves of *Cistus laurifolius L.*	Square porous (63% opening)
Madrigal et al. (2012) [6]	Mass loss calorimeter Oxygen bomb calorimeter Full scale (outdoor wind tunnel)	50 - -	Shrubs	Square porous (63% opening) - -
Madrigal et al. (2012) [30]	Mass loss calorimeter	25 and 50 50	Pine needles Leaves and twigs of shrub species	Square porous (63% opening)
Possell et al. (2012) [31]	Mass loss calorimeter	25	Eucalyptus foliage	Square porous (27% opening)

During wildland fires, radiant heat fluxes typically range from 50 to 250 kW/m^2 [32]. Based on literature review presented in Table 1, most research are conducted for heat flux up to 50 kW/m^2.

The critical heat flux necessary for ignition is the heating rate that balances the cooling rate and consequently raises the temperature precisely to the moment at which ignition will occur. This value depends on heat transfer, weather conditions, and fuel properties, including its ignition temperature, porosity, compactness, and moisture content. Sabi et al. (2021) propose a new method for estimating the critical heat flux for the ignition of porous fuels. They compare the experimental data obtained from the cone calorimeter with analytical and numerical results from a model that incorporates energy and temperature ignition criteria. The experimental setup aimed to investigate the probabilistic ignition behavior observed in the critical region, which is ignored by deterministic methods used in literature for estimating the critical heat flux for ignition [33].

3. FUEL MOISTURE AS MAIN DRIVER OF FOREST FLAMMABILITY

The moisture content (MC) stands out as the crucial fuel factor influencing the behavior of wildfires. Moisture content is traditionally reported in the literature on a dry weight basis, expressed as a percentage of oven-dry weight. This can be calculated using the following equation:

$$\text{MC\%} = \frac{\text{fresh weight - dry weight}}{\text{dry weight}} \times 100\% \tag{1}$$

Moisture content influences nearly all fire processes, like ignition, combustion, and smoldering. High level of moisture content can slow the rate of burning and fuel consumption. Upon exposure to heat, the water is the first to evaporate, slowing down the ignition and combustion process. If the ignition occurs, with a higher level of moisture content, it can result in less flaming combustion but increased smoldering, and decreased fuel consumption [34].

The classical combustion model assumes that all moisture will initially evaporate from the sample at a temperature near the boiling point of water. However, Picket et al. (2010) revealed that substantial amounts of moisture persisted in the individual samples even after ignition [35].

Most flammability experiments on forest vegetation involve dead ground fuels with very low moisture content. The primary hypothesis in this line of research is that wildfires in many ecosystems are dominated by ground fuels with moisture contents less than 5% on an oven-dry weight basis.

The oscillation of moisture content in dead fuels can be best understood by considering the concept of equilibrium moisture content. Equilibrium moisture content refers to the period when fuel particles neither gain moisture from the air and environment nor lose moisture. Fuel particles reach equilibrium moisture content when the water vapor pressure within the particle matches the vapor pressure of the air in contact with its surface, preventing any moisture exchange between the air and the wood fuel. However, this equilibrium state is rarely achieved in nature because air temperature, humidity, and solar radiation continually fluctuate throughout the day and night [2].

Research on the combustion characteristics of live fuels is limited, due to the assumption that live fuels behave like wet dead fuels. Jervis and Rein (2016) discovered that live *Pinus halepensis* needles ignite approximately four times slower and burn with lower power and heat of combustion compared to dead needles. Oven drying of live samples results in significant variations in fire behavior, indicating that drying conditions and changes in plant chemistry are crucial factors [24].

On the other hand, some researchers focus on the differences in the burning behavior of live and dead leaves. In the article [36], the authors conducted measurements to analyze flame patterns and retained moisture in live and dead leaves. The live groups had approximately 34% and 63% moisture content, while the dead groups were dried to about 4% moisture content, with one group rehydrated back up to 26% moisture content. The results indicate that the temperatures, slopes, and durations of rehydrated and dehydrated leaves differed. This suggests that moisture held in live leaves has a stronger effect on leaf temperature than moisture held in dead leaves.

McAllister et al. (2012) investigated the thermal behavior of both live and dry needles, collecting samples throughout the growing season to analyze variations in moisture content and chemical composition. The study compares the ignition behavior of live fuels, specifically lodgepole pine and Douglas-fir, through piloted ignition experiments. It evaluates various correlations from the literature for ignition time concerning moisture content and finds that these correlations do not accurately capture the trends with live fuels [32].

Jolly et al. (2012) explore the fuel characteristics and ignition potential of *Pinus contorta* (lodgepole pine) foliage in the initial phases of a mountain pine beetle attack. The study measures the fuel moisture content, chemical composition, and time to ignition of needles across various attack categories. Understanding the time to ignition of needles assists in determining the minimum surface fire intensity needed for a fire to escalate into the crowns of trees. Reduced moisture content and alterations in foliar chemistry amplify the flammability of mountain pine beetle-attacked trees, indicating an increased likelihood of crown fires in affected stands as long as foliage is retained on the trees [37].

The study in [38] explores the influence of moisture on the combustion of pyrolysis gases in wildland fires. The moisture released from vegetation during pyrolysis impacts the characteristics of the gaseous flame and the temperature distribution within both opposed diffusion and premixed laminar flames. The findings indicate that the presence of water vapor derived from vegetation moisture influences the distribution of key gas components, including O_2 and H, in both non-premixed and premixed flames.

Pinto et al. (2020) present a novel approach to influence the moisture content on the radiant heat flux emitted by a laminar non-premixed flame. With increasing moisture content, both flame height and mass loss evolution decrease, resulting in a decrease in the radiant fraction emitted. Interestingly, the research indicated that the fuel moisture content does not alter the shape of the flame, which is modeled as a cone. Both flame height and radius diminish as fuel moisture content increases. Notably, the variable with the most significant impact on the flame's radiative behavior over time is the mass loss rate [39].

Some authors have played a key role in driving the ongoing development of new approaches to determine the flammability parameters of wildland fuels, particularly those related to moisture content. The study in [30] introduces a novel bench-scale methodology that integrates the use of a mass loss calorimeter and a moisture analyzer to estimate flammability parameters and assess fuel moisture content. This approach ensures fixed conditions for laboratory tests. The proposed method is directly applicable to forest fuels in devices with the same configuration, such as the cone calorimeter and the fire propagation apparatus.

Precise assessment of flammability is essential to enhance understanding of the risk of vegetation fires. Research in [40] offers insights into the flammability characteristics of tree species, helping to identify suitable species for fuel brakes in forest fire prevention based on varying moisture content.

In addition to moisture content, the authors in [41] underscore the importance of employing appropriate testing methods, sample preparation, and considering factors such as sample size and moisture content when investigating the flammability of wildland fuels using bench-scale devices. Their study reveals significant influences of fuel bed diameter and moisture content on the ignition and burning behavior of Eucalyptus leaves. Additionally, the increase in emission factors for volatile organic compounds (VOCs) with higher fuel moisture content underscores the importance of considering moisture levels when assessing the impact of fire on air quality [31].

Regarding the flammability of live forest fuels, the study [32] suggests that moisture content alone is not sufficient to predict the ignition time of live fuels, as there is another mechanism controlling ignition time. The thermal properties of live foliage, such as density, thermal conductivity, and specific heat, are largely unknown and may influence the ignition time of live fuels. Similarly, the results of the study in [24], show that there are fundamental differences in the physics and chemistry of the flames of live, aged, and dead needles, and that moisture content alone cannot account for the variations in burning behavior.

4. INFLUENCE OF IGNITION TYPES ON BURNING OF FOREST FUELS

Combustion is a chemical reaction involving fuel and oxidizer, leading to the rapid release of energy in the form of heat and light [42]. This process subsequently results in the production of various chemical products. Upon exposure to thermal radiation, the surface temperature of the samples increases, leading to the production of pyrolysis gases. As the pyrolysis temperature is reached and continues to rise, fuel gases may become visible, transforming into more reactive gases in larger quantities. At this stage, pyrolysis gases begin to mix with the surrounding air, and as the temperature rises further, the lower flammability limit is reached. At this point, any external spark can ignite the formed gaseous mixture [2]. An important feature of calorimetric devices is the capability to use piloted ignition, such as an electric spark. This ignition method accelerates the local reaction and heat release rate, which then continues as self-sustaining combustion of the sample. In the references listed in Table 1, primarily involving calorimetric devices, piloted ignition in the form of an electric spark was employed.

McAllister et al. (2012) investigated the piloted ignition behavior of live fuels, considering their moisture content and chemical composition throughout the growing season. The study aimed to test the applicability of existing correlations for predicting live fuel ignition based on moisture content alone [32]. Mindykowski et al. (2011) determined the critical (minimum) heat flux for the piloted ignition of wildland fuel litters (needles and leaves) by employing the Fire Propagation Apparatus (FPA). The assumption is made that ignition occurs precisely when the average temperature within the penetration depth of radiation attains a critical value [43].

Another type of ignition is self (auto)-ignition, also known as spontaneous ignition, which depends on the balance between the heat produced and the heat given to the environment. Spontaneous ignition requires a higher gas phase ignition temperature than that required for piloted ignition [2]. Tihay-Felicelli et al. (2016) performed autoignition experiments in a cone calorimeter to investigate the effect of the diameter of dead twigs on flammability parameters such as time to ignition, surface temperature and mass loss [44].

One characteristic of the spread of forest fires in urban environments is the generation of combustible fragments from burned forest biomass, that once lofted, become firebrands. Upon depositing on vegetative fuels, firebrands with sufficient energy initiate the ignition processes. They can initiate either a smoldering combustion reaction or a flaming combustion reaction. Understanding the transport and ignition of firebrands presents a significant challenge, particularly in dealing with the actual showers of firebrands generated in wildland and Wildland-Urban Interface (WUI) fires [45].

To investigate structural vulnerabilities resulting from firebrand showers, Manzello et al. (2011) conducted a series of full-scale tests to quantify firebrand penetration through building vents. The aim was to determine whether firebrands have the potential to accumulate in front of structures and ignite materials placed nearby [46]. The research presented in the [47] examines the spontaneous ignition time of idealized firebrands under controlled radiative heat flux, including variations in the physical characteristics of the fuel litter.

Reszka et al. (2020) presented additional research exploring the types of ignition. The authors analyze continuous and discontinuous types of ignition. Continuous ignition is characterized by a heat flux from a radiative and/or convective source, while discontinuous ignition involves the transfer of mass and energy due to the transport and landing of hot particles, such as embers or firebrands. This paper addresses the need to experimentally and theoretically determine whether firebrands are capable of igniting live vegetation. This underscores the importance of understanding the role of firebrands in fire propagation and the ignition of live vegetation [48].

5. CONCLUSION

Based on the literature search discussed in this paper, the overarching conclusion is that the scientific community has not established a standard methodology for determining the flammability characteristics of forest vegetation. Among the devices whose working principles are determined by international standard organizations, those operating on the principles of calorimetry (fire propagation apparatus, cone calorimeter, mass loss calorimeter) stand out. Among researchers worldwide addressing this issue, the literature reveals numerous commercial devices for determining the flammability characteristics of forest vegetation, as well as devices created as personal innovations by researchers. Additionally, the data obtained from these devices can serve as input information in various systems, providing decision support for managing forest fires.

A limiting factor in comprehending the spread and development of wildfires, attributed to high expenses, is the implementation of large-scale experiments. To overcome this limitation, various numerical models based on the principles of numerical fluid dynamics have been developed to attain the desired results. Extensive statistical analyses were employed to process the data and draw general conclusions about the dynamics of forest fire development.

The references analyzed in this literature review reveal that research on the flammability of forest vegetation predominantly concentrates on surface dead fuels, with limited attention given to canopy fuels. In particular, the lack of canopy fuel analysis on devices that work on the principle of calorimetry was noticed. In the application of these devices, a widely accepted approach involves preparing samples on custom-made sample holders, intending to analyze their position to correspond with the field position. Given the existence of various sample holder configurations, future research should focus on determining reliability coefficients for the application of different sample holders.

Predicting the ignition time of a forest fuel based solely on moisture content is not sufficient, as numerous mechanisms control the ignition time of a fuel. Characterizing the flammability of forest fuel solely based on flammability parameters (such as heat released, flame geometry, temperature, etc.) obtained by numerous experimental methods is not possible without considering the physical and chemical characteristics of the fuel.

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PREGLED LITERATURE KLJUČNIH NALAZA U FUNDAMENTALNIM ISTRAŽIVANJIMA ŠUMSKIH POŽARA

Svrha ovog pregleda je da izvrši ispitivanje ključnih nalaza u fundamentalnim istraživanjima karakteristika upaljivosti šumskih požara. Pregled počinje kratkim uvodom, naglašavajući rastuću potrebu za detaljnijim istraživanjem razvoja šumskih požara usled sve izraženijih klimatskih promena. Zatim sledi pregled primene uređaja koji rade na principu kalorimetrije, sa akcentom na dodatne mogućnosti podešavanja i prilagođavanja tih uređaja. Pregledom literature postaje evidentno da je većina istraživanja o zapaljivosti šumske vegetacije prvenstveno usmerena na nivoe vlage u gorivima. Iz tog razloga, treći deo ovog rada posvećen je uticaju sadržaja vlage na upaljivost šumske vegetacije. Na kraju je dat pregled vrsta i mogućnosti paljenja šumskog goriva, sa posebnim naglaskom na stvaranje tinjajućeg žara kao izvora paljenja vegetativnog goriva.

Ključne reči: *šumski požari, kalorimetrija, sadržaj vlage, tipovi paljenja*.