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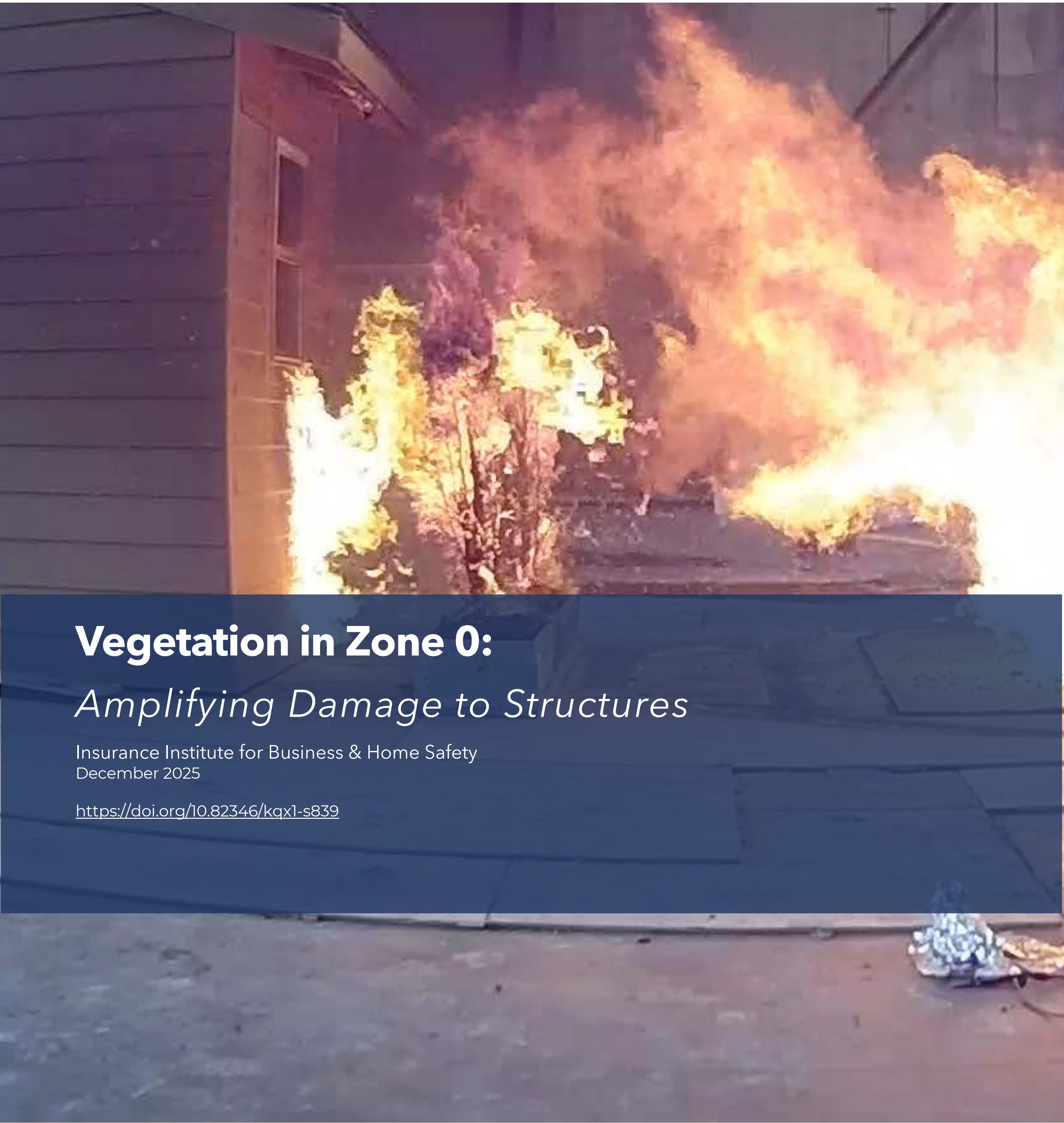

Vegetation in Zone 0:

Amplifying Damage to Structures

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Vegetation in Zone 0—the first five feet around a home—increases the intensity of the heat exposure the building experiences and can amplify the damage to homes during a wildfire. While established research defines the importance of the 5-foot noncombustible zone, IBHS conducted a series of tests specifically focused on the impact of vegetation within this area.

Key Takeaways:

- **Damage Amplifiers:** Vegetation in Zone 0 amplifies the damage to homes, increasing the likelihood of structure ignitions and the severity of damage.
- **Moisture:** Even well-hydrated plants will ignite and burn in conditions common during a suburban wildfire conflagration. The moisture content of plants increases the time to ignition, which in turn allows the structure to preheat longer, making the structure more susceptible to ignition when the vegetation in Zone 0 ignites.
- **Wind & Interventions:** Local wind environments influence wind speed and direction. These fluctuations, along with firefighter interventions, help explain some of the contrasting observations regarding consumed and unconsumed vegetation documented in the field during post-event damage investigations after a conflagration.

Figure 1. Examples of the range of damage observed to homes and vegetation during post-event damage investigations. Figure (a) shows damage documented during an IBHS field investigation in LA after the Palisades Fires (2025). Figures (b), (c), and (d) are courtesy of CAL FIRE.

Plant Moisture

Live fuel moisture content plays a key role in determining the fire behavior of live vegetation. The higher the moisture content, the more water must evaporate before fuel gases are released and combustion can begin.

In discussions with numerous stakeholders, IBHS researchers have found that moisture content is expressed in two distinct ways: dry basis and wet basis. These two different definitions of moisture content often lead to misunderstanding and confusion when talking about scientific results and in policy discussions. Therefore, it is critical to clearly specify which definition of moisture content is being used when discussing vegetation characteristics.

For live vegetation, moisture content is usually expressed on a dry basis as

$$Moisture\ Content_{Dry\ Basis} = \frac{(Mass_{initial} - Mass_{final})}{Mass_{final}} * 100,$$

where the mass of water in the sample is compared to the dry mass of the plant. Because this ratio can exceed 100%, dry-basis values may appear high but accurately reflect the amount of water relative to dry fuel.

Moisture content can also be expressed in wet basis as

$$Moisture\ Content_{Wet\ Basis} = \frac{(Mass_{initial} - Mass_{final})}{Mass_{initial}} * 100,$$

using the total mass of the plant instead of the dry mass in the calculation. Since the mass of water is part of the denominator, wet-basis moisture content is always lower than dry-basis moisture content. As illustrated in Figure 2, it is essential to specify which moisture content calculation is being used to avoid miscommunication or misinterpretation of results. In practice, fire services often use dry-basis moisture content measurements with 60% dry-basis moisture content described as very dry and volatile fuels; by contrast, a 60% wet-basis value represents a well-hydrated plant.

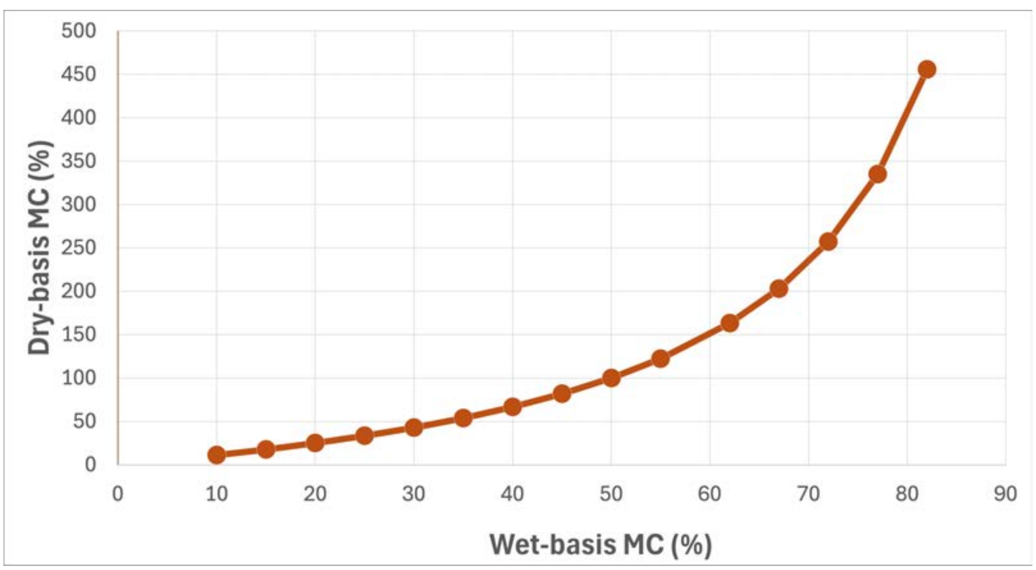

Figure 2. Relationship between wet-basis moisture content (MC) and dry-basis moisture content.

Experiments

IBHS conducted 17 experiments using two burning wood cribs[1] to simulate a neighboring structure[2] (e.g., a small shed) that ignited. A target structure was placed 20 ft downwind of the wood cribs, and well-hydrated shrubs (arborvitae) were placed in the target structure's Zone 0 (i.e., within 5 ft of the target) in several different configurations. Three tests included no shrubs. In 13 of the 14 tests with shrubs, well-watered shrubs yielding an average dry-basis moisture content above 160%, or a wet-basis moisture content of 60%, were used. One test in the 90-degree configuration was conducted with dry vegetation.[3] The tests were conducted at an approximate wind speed of 25 mph at two different orientations to the wind, as summarized in Table 1 and shown in Figure 3. The target structure featured a 1-hour fire-rated wall assembly with a double-pane window and open eaves.

Table 1. Summary of the 17 tests conducted across 3 configurations and the resulting damage to the target structure.

Experimental Scenario	Count of Target Ignitions and Tests	Observed Damage
Base case: No shrubs	0 ignitions out of 3 tests	• Cracked windowpane
Shrubs in Zone 0: 0 degrees to the wind	3 ignitions out of 11 tests	• Broken windowpane • Windowpane fell out • Melted window frame • Charred fascia • Charred and discolored siding
Shrubs in Zone 0: 90 degrees to the wind	0 ignitions out of 3 tests	• No damage • Cracked windowpane

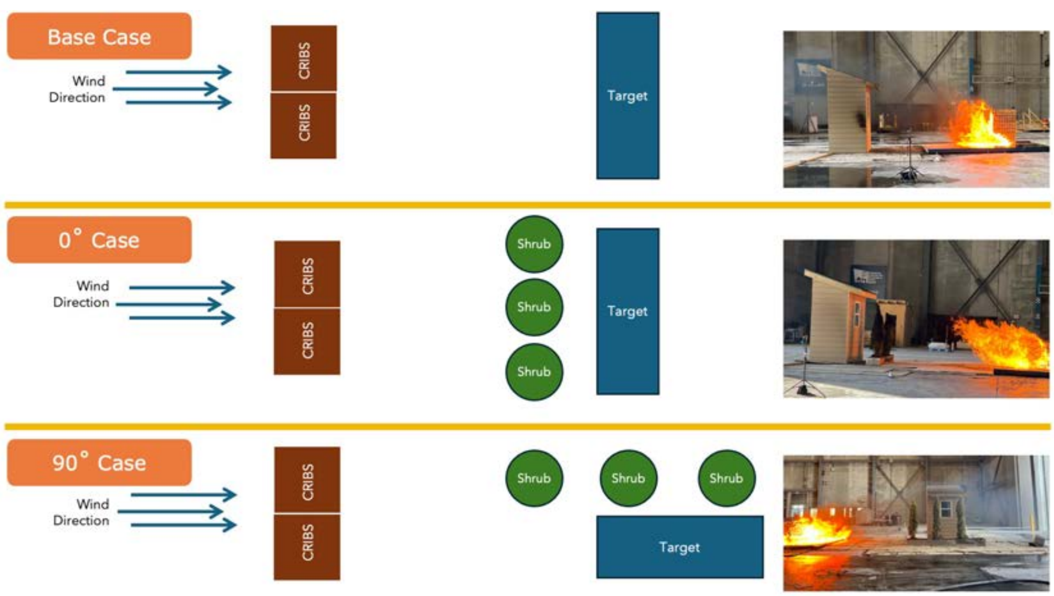

Figure 3. Experimental setup for each of the 3 scenarios including a photo of the configuration.

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[1]Wood crib dimensions: 3-ft × 3-ft × 2-ft 10½ in.; total mean fuel load per experiment: 692 +/- 36 pound.

[2]A similar fuel load was used by the National Institute for Standards and Technology (NIST) in experiments to represent exposure from a small shed generating a peak heat flux of approximately 30 kW/m² when located 10 ft from the target. For additional information, see NIST Technical Note 2253.

[3]Average dry-basis moisture content below 25%, or a wet-basis moisture content of 20%.

(a) *(b)*

Figure 4. Example of the increased damage when shrubs are present. (a) shows the cracked windowpane damage from the base case without shrubs. (b) shows the damage amplification when shrubs were present including discoloration to the siding and the broken windowpane. In (b), the missing pieces of glass in the broken window create an opening in the building envelope for flames and embers to enter the structure.

In the experiments, when shrubs were not present in Zone 0 (base case), the only observed damage to the target was a cracked windowpane (Figure 4a); no ignition of the structure occurred. In contrast, when shrubs were present, radiant and convective heat from the burning cribs dried the shrubs to the point of ignition. Once ignited, the arborvitae in Zone 0 acted as connective fuel, increasing the likelihood and severity of damage to the structure. This shrub ignition consistently amplified the damage to the target structure compared to the base case, either by creating openings for flames and embers to enter the structure—through damage to the vinyl window frame or breakage of the windowpane (Figure 4b)—or by causing ignition of the structure (Figure 5). In the three tests where ignition of the target occurred, flames from the shrubs ignited the siding (Figure 5a) or the eave (Figure 5b). The siding ignited 10 seconds after the initial ignition of the shrubs, demonstrating the speed at which connective fuels can spread fire to a structure. Eave ignitions occurred 6 seconds after the initial ignition of the shrubs and briefly sustained flames for about 10 seconds.

The range of resulting damage arises from differences in the fire development of both the heat source—the wood cribs—and the vegetation itself. While the wood cribs were constructed identically in size and packing ratio and conditioned to limit variation in moisture content, the natural variation in the density of wood introduces some variation in mass. In contrast, the plants exhibited variability not only in moisture content and mass but also in size and packing ratio. Because plants are living organisms, their characteristics naturally vary. When test parameters

(a) *(b)*

Figure 5. Example of (a) siding ignition and (b) eave ignition observed during 0 degree to the wind exposure.

control for plant size—such as height or width—it is not possible to simultaneously control for mass and packing ratio, since the density of the plant varies naturally, even amongst plants of the same species. This variability affects how each shrub burns and, consequently, the exposure created to nearby building materials. This natural variation in vegetation inherently means that there will be significant variability between seemingly identical configurations, even in a controlled laboratory setting.

To quantify the role of vegetation in structural ignitions, heat flux data was collected on the target in both areas shielded by the vegetation and areas directly exposed to the radiation from the burning cribs (Figure 6). In the case where the target building ignited, the mean heat flux on areas shielded by the shrubs in Zone 0 prior to ignition was lower than in areas directly exposed to the radiation. However, heat flux measurements on the target showed that both areas shielded and unshielded by the shrubs eventually achieved heat fluxes close to the critical ignition threshold of different siding materials determined from cone calorimeter testing[4]. This creates the potential to ignite the wall cladding if a spark or other piloted ignition source is present, such as a shrub. The unshielded portions of the wall reached this threshold earlier, and when the vegetation ignited, it added sufficient thermal insult to the wall to cause the unshielded portions to ignite and subsequently spread flames to the shielded sections of the wall. While this finding indicates that shrubs or other obstacles can provide some relief to the thermal exposure from surrounding structures, if this shielding is provided by combustible materials, the shielding effect is temporary and, if those combustible materials ignite, they create an even larger ignition risk to the structure.

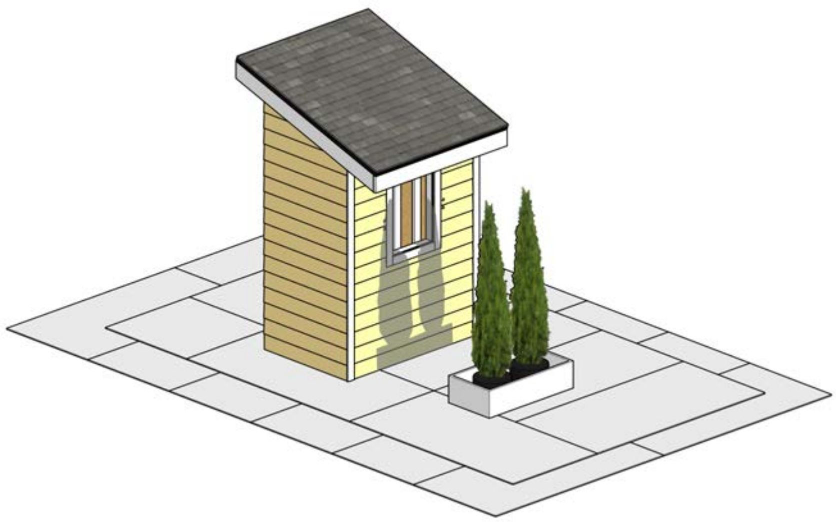

Figure 6. Shielded (shown in gray) versus unshielded (shown in yellow) areas on the target structure.

Drying and Preheating Times

While dry vegetation is more likely to ignite than well-hydrated vegetation, increasing the moisture content of the vegetation does not fully remove the vulnerability in Zone 0. Well-hydrated plants may resist ignition under isolated, low-intensity exposure, but the scale of the heat and flame exposure during suburban conflagrations can quickly dry even well-watered vegetation, making them susceptible to ignition.

While not the most extreme case, these experiments showed how quickly this drying can occur under conditions typical of a conflagration. These shrubs were exposed to intense radiant heat and significant convective heating from the burning cribs. The wind heated by the burning cribs preheated downstream surfaces, including the vegetation and the target. This convective heating rapidly dried the vegetation—a process that would have occurred much more slowly if only radiation were present (i.e., if there was no wind present). Figure 7 shows the well-hydrated shrubs at the beginning of one of the experiments and then 13 minutes later—just seconds before they ignited. The change in color of the vegetation clearly illustrates the drying effect caused by the intense convection and radiant heat.

[4] For critical ignition thresholds, see Table 9 in the *Ignition Handbook: Principles and Applications to Fire Safety Engineering, Fire Investigation, Risk Management and Forensic Science* (Babrauskas, 2014).

(a) *(b)*

Figure 7. Effect of the heat exposure on drying well-hydrated vegetation. (a) Close-up of the shrubs at the beginning of the experiment, showing them fully hydrated. (b) Close-up 13 minutes after ignition of the cribs, showing the shrubs have dried out just before ignition.

These experiments highlight the need to look at vegetation and the built environment as a system and not as independent components. As shrubs dry, the heat simultaneously primes the nearby building materials for ignition. As shown in Figure 8, when the starting moisture content of the shrubs is higher, the drying period is longer, which allows longer for the temperature of nearby building materials to rise to temperatures susceptible to ignition. These temperatures make the building materials much more likely to ignite with any increase in thermal exposure (i.e., ignition of the shrubs).

The increased likelihood of ignition because of the duration of preheating was observed in this series of experiments. This observation is critically important in guiding future work to evaluate the effects of preheating time and exposure to building materials in the presence of combustible materials in Zone 0 and Zone 1 (5-30 ft) during a suburban conflagration.

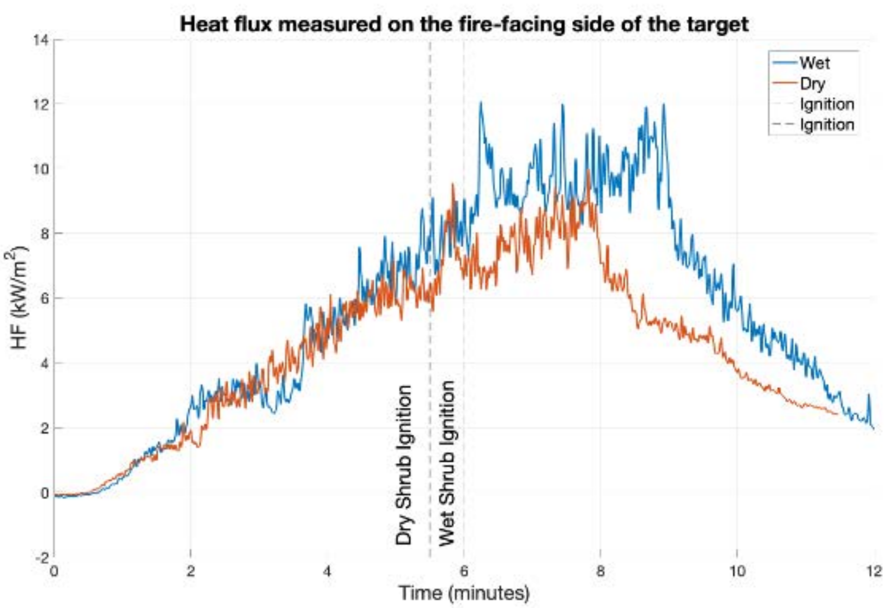

Figure 8. Heat flux measurements on the target structure during two tests in the 90 degrees to the wind configuration. The dry shrub ignited sooner, while the well-hydrated shrub took longer to ignite, giving the target structure longer to preheat.

Wind Direction

All of the experiments in this study were conducted under a constant wind speed of approximately 25 mph, representing a relatively moderate wind under which suburban conflagrations typically occur.[5] However, two different relative wind directions were examined.

In the first configuration, shown in Figure 3, shrubs were positioned windward of the target structure, creating a downwind exposure between the burning wood cribs, the shrubs, and the wall. Under these conditions, all shrubs received similar heat exposure from the burning cribs, ignited almost simultaneously, and the green plant matter was fully consumed as shown in Figure 9a.

(a) (b) (c)

Figure 9. Remains of vegetation after experimental testing (a) at 0 degrees to the wind, and (b) and (c) at 90 degrees to the wind.

In the second configuration (90-degrees case in Figure 3), the target and vegetation were rotated 90 degrees while maintaining the same distance from the cribs. In this crosswind configuration, the shrub closest to the burning cribs ignited first, acting as a localized secondary heat source to the target. The subsequent shrubs were only partially consumed, as they received a lower heat exposure from the burning cribs and likely retained a higher moisture content (Figure 9b and Figure 9c).

As expected, these experiments show that wind direction strongly influences heat exposure to the target structure. In the downwind configuration, the structure faced greater heat exposure as flames produced by the burning shrubs were driven toward the target structure by the wind, intensifying radiant and convective heat exposure and increasing the likelihood of ignition. By contrast, the crosswind configuration resulted mainly in radiant heat exposure and occasionally flame contact from the burning shrubs as wind carried flames downstream, away from the target structure. This reduced crosswind exposure corresponded with the level of damage observed during the three tests conducted at this wind orientation, where shrub ignition caused either cracking of windowpanes or no damage at all but did not lead to ignition of the target structure.

(a) (b) (c)

Figure 10. Examples of the impact of the local wind direction exemplified in Altadena, California following the Eaton Fire (2025).

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[5] *For example, during the Palisades Fire, CAL FIRE incident logs note wind gusts of 60 mph and during the Lahaina Fire, NASA notes recorded gusts as high as 67 mph. Red Flag conditions in Southern California typically include sustained winds of 25 mph.*

These findings, coupled with the natural variability of vegetation, help explain the range of outcomes observed during post-event damage investigations, including those following the 2025 Eaton and Palisades Fires. In several cases, vegetation adjacent to destroyed structures was only partially consumed (Figure 10a). Consistent with the laboratory results, in some cases partially consumed vegetation produced minor damage—such as the discolored stucco wall shown in Figure 10b—although the building material resisted ignition. In contrast, exposure from nearly fully consumed vegetation, as illustrated in Figure 10c, resulted in more severe damage, where burning shrubs ignited the eave before firefighters extinguished the flames. Given that the local wind characteristics vary in every wildfire event and around each parcel, this variability cannot be accounted for in mitigation strategies.

Discussion

Across 17 experiments, vegetation in Zone 0—regardless of moisture content and the inherent variability of living organisms—exhibited a consistent pattern of amplifying damage to the target structure. Live fuel moisture content of vegetation and the wind influence how and when shrubs will burn. Dry shrubs ignited earlier than wet shrubs, limiting preheating of the structure. However, once ignited, dry shrubs burned more intensely than wet shrubs causing a larger additional thermal insult to the structure. While ignition of the wet shrubs added a lower thermal insult, it allowed for longer preheating times, which increased the ignition potential of the building materials. This highlights the complexity between the intensity of the added thermal insult of the burning vegetation and the increased susceptibility of longer preheating times, both of which are a function of the vegetation moisture content.