STORM
Safeguarding Cultural heritage through Technical and Organisational Resources Management

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ISA
ISTITUTO SUPERIORE ANTINCENDI

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Emergency Management of Cultural Heritage

Principles to face risks for Cultural Heritage – Forest Fires

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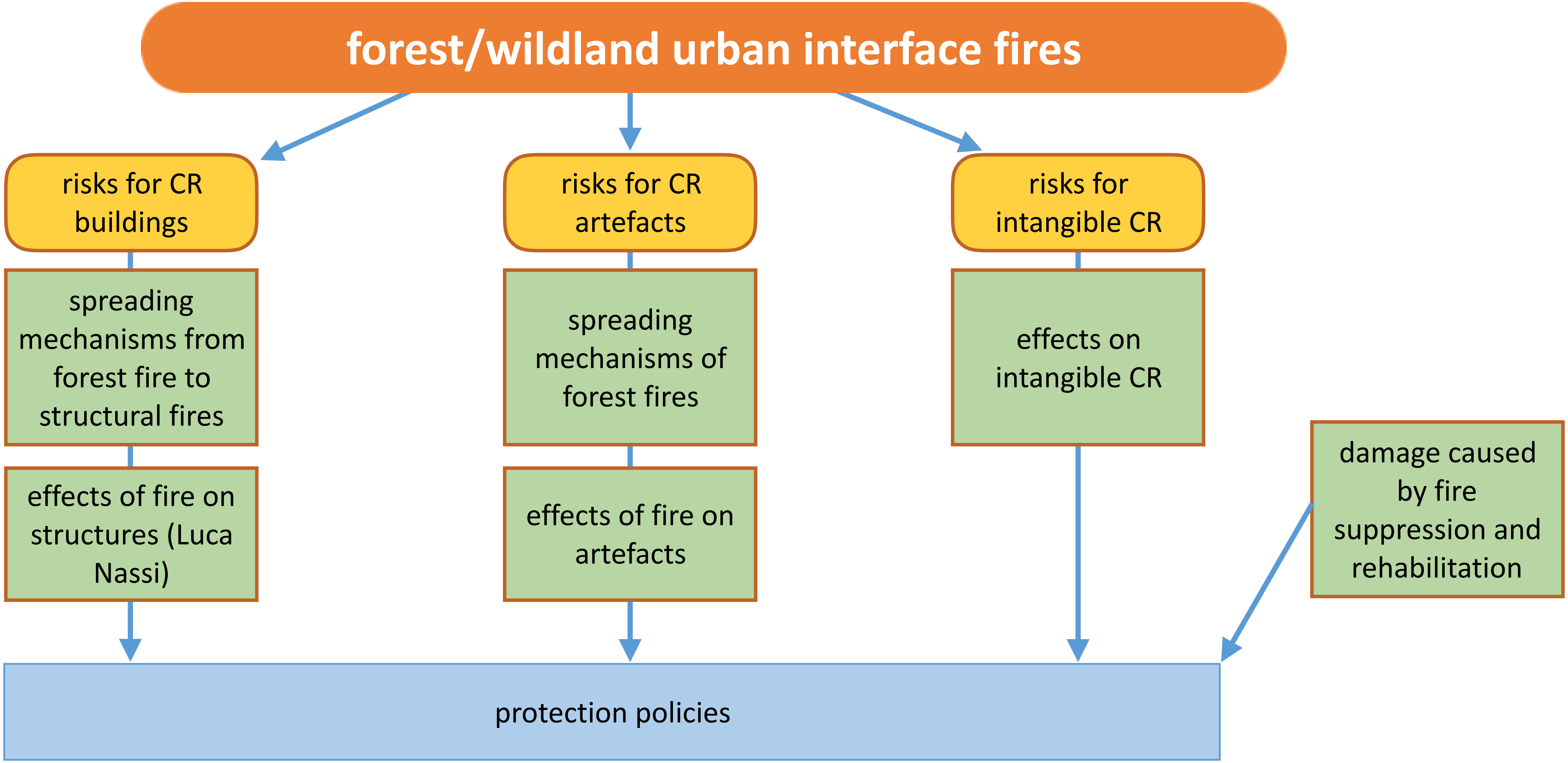
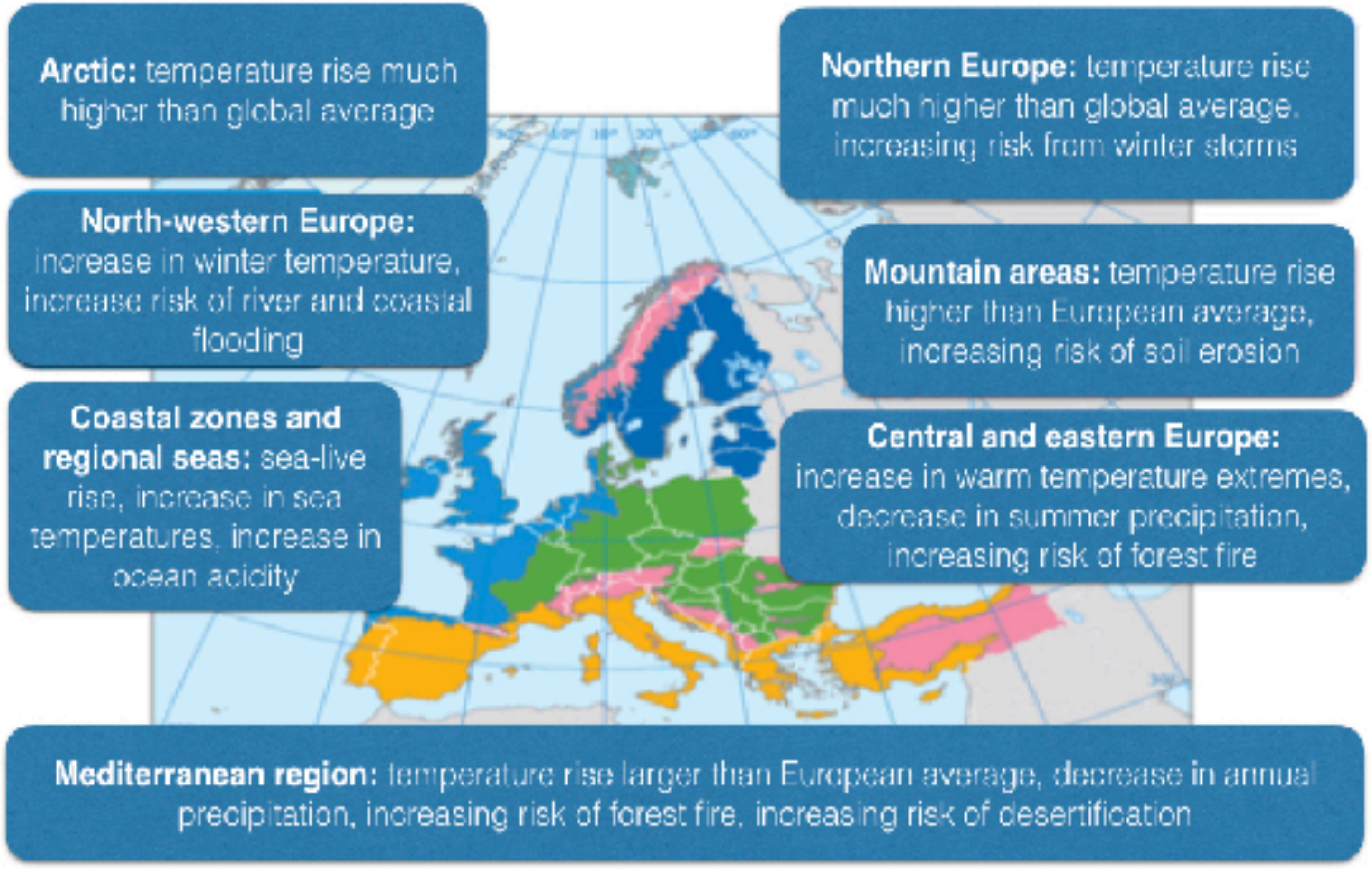

forest/wildland urban interface fires
risks for CR buildings
risks for CR artefacts
risks for intangible CR
spreading mechanisms from forest fire to structural fires
spreading mechanisms of forest fires
effects on intangible CR
effects of fire on structures (Luca Nassi)
effects of fire on artefacts
damage caused by fire suppression and rehabilitation
protection policies

Summary

- Cultural heritage and fires: a risk from wildland fires?
- Spreading mechanism of forest fires
- Spreading mechanism from forest to structural fire
- Effects of fire on structures (vd Nassi)
- Effects of vegetation fires on artefacts
- Effects of fire on intangible cultural heritage
- Damage caused by fire suppression and rehabilitation
- Conclusions

1 -Cultural heritage and fires: a risk from wildland fires?

Cultural heritage and fires: a risk from wildland fires?



Redrawn from: Climate change, impacts and vulnerability in Europe 2012: an indicator-based report. European Environment Agency Report

… may lead to more forest fires due to warmer and drier weather, and possibly increases in lightning storms (a natural cause of fires) …

Cultural heritage and fires: a risk from wildland fires?

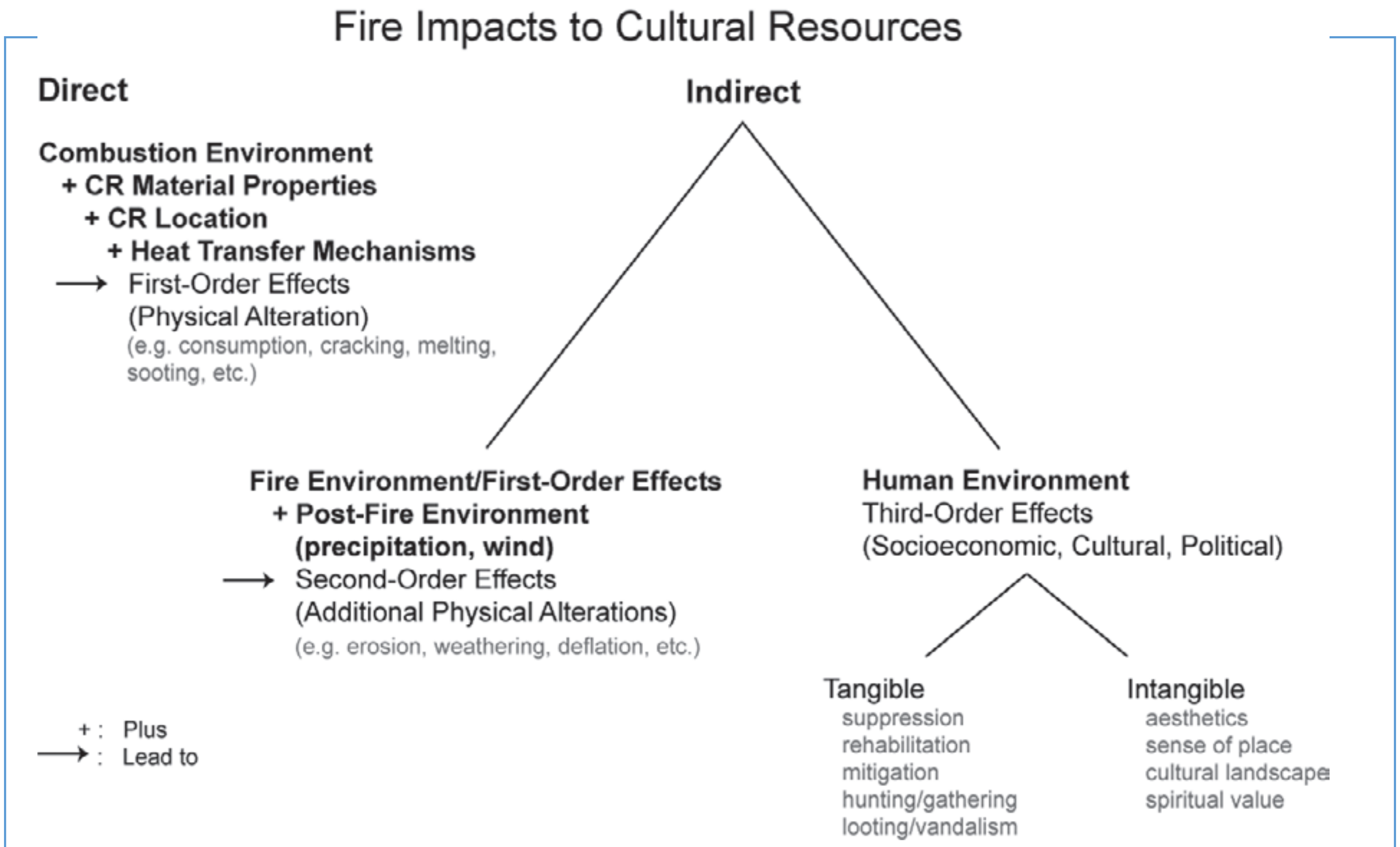


Figure 1-3—Fire impacts on cultural resources. Direct, First-Order effects result from biophysical processes related to the local combustion environment as it is juxtaposed to cultural resources and the physical properties of the resource. Indirect effects derive from biophysical processes following the fire (Second-Order effects) or human responses to fire (Third-Order effects) (synthesized from numerous sources).

Figure from [2]

On 10 March 2012, the castle of Krasna Horka in Slovak Republic caught fire, allegedly due to burning of dry grass by two children who were trying to light cigarettes…

http://www.fireriskheritage.net/case-hystory/castle-destroyed-by-grass-fire-2/

Fire Effects on Materials of the Pre-historic and Historic Period

The Effects of Fire on Subsurface Archaeological Materials

Effects of Fire on Intangible Cultural Resources

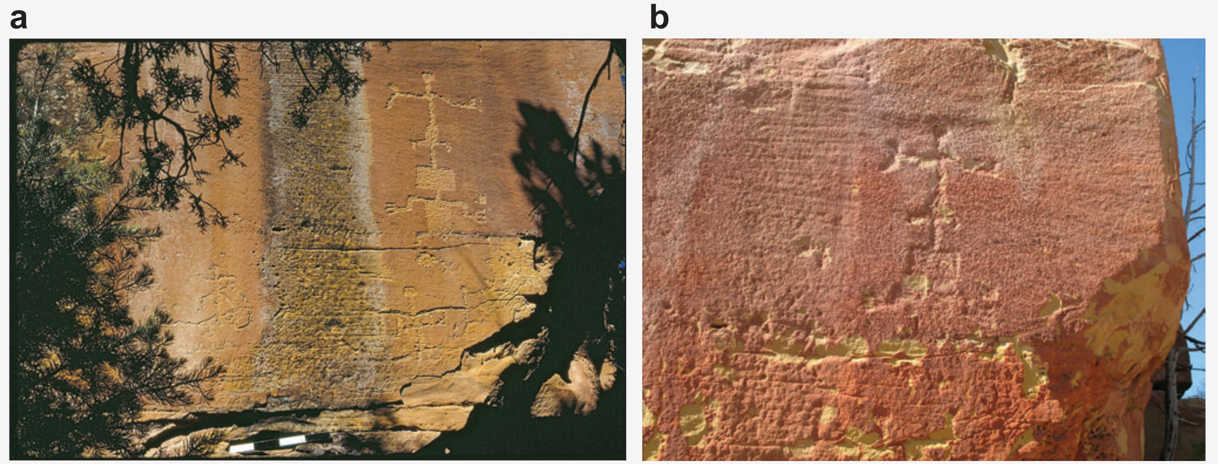
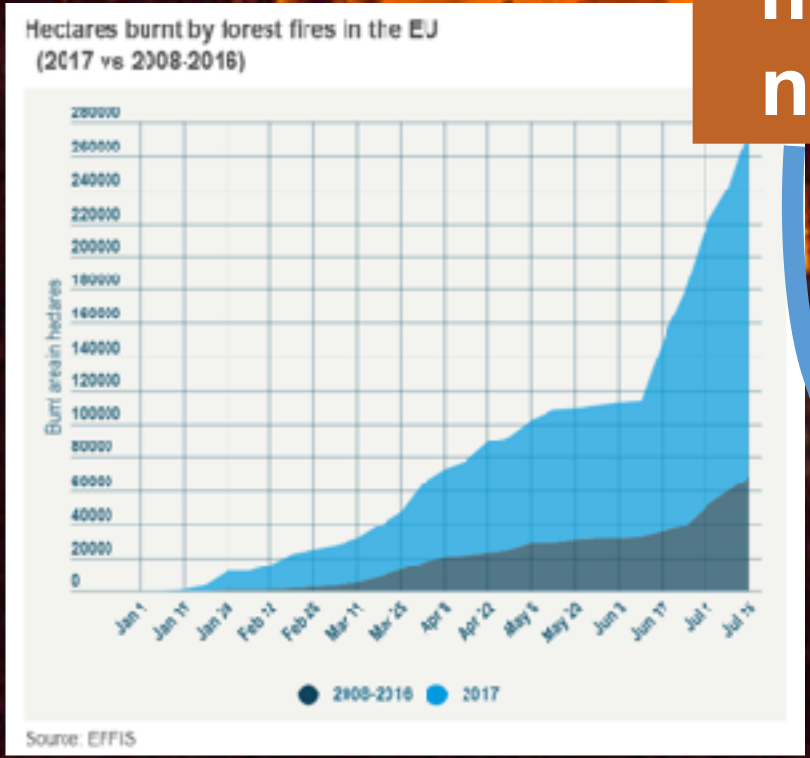


Figure 5-S1—Direct effects of the 1996 Chapin-5 Fire, Mesa Verde National Park, Colorado on the Battleship Rock petroglyph; Panel 3R, before (1989) (a) and after (2006) (b) (compliments of S.J. Cole).

Cultural heritage and fires: a risk from wildland fires?

Mega-fires manage to thwart all efforts to control them until firefighters get a favorable change in weather or until they burn all available fuel

megafires are increasing in number and frequency



- **larger parts of territory are involved**
- **firefighting resources aren’t adequate**

2 - Spreading mechanism of forest fires

Spreading mechanism of forest fires

- **pre-heating**
- **flaming combustion**
- **smouldering**

(a)

(b)

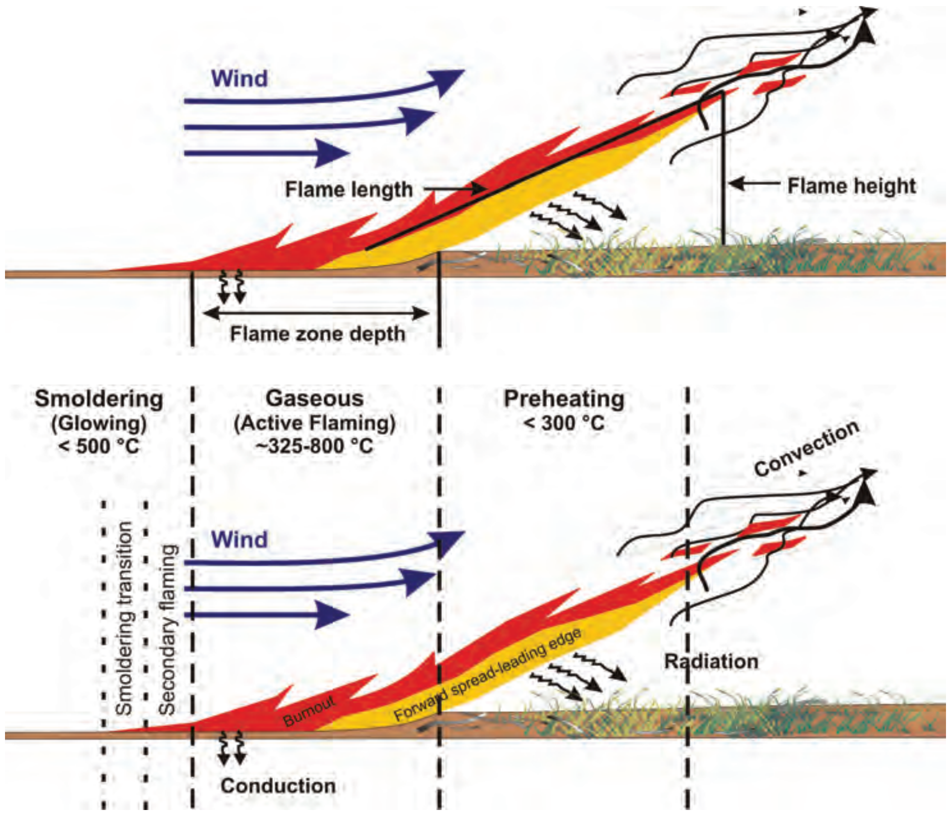


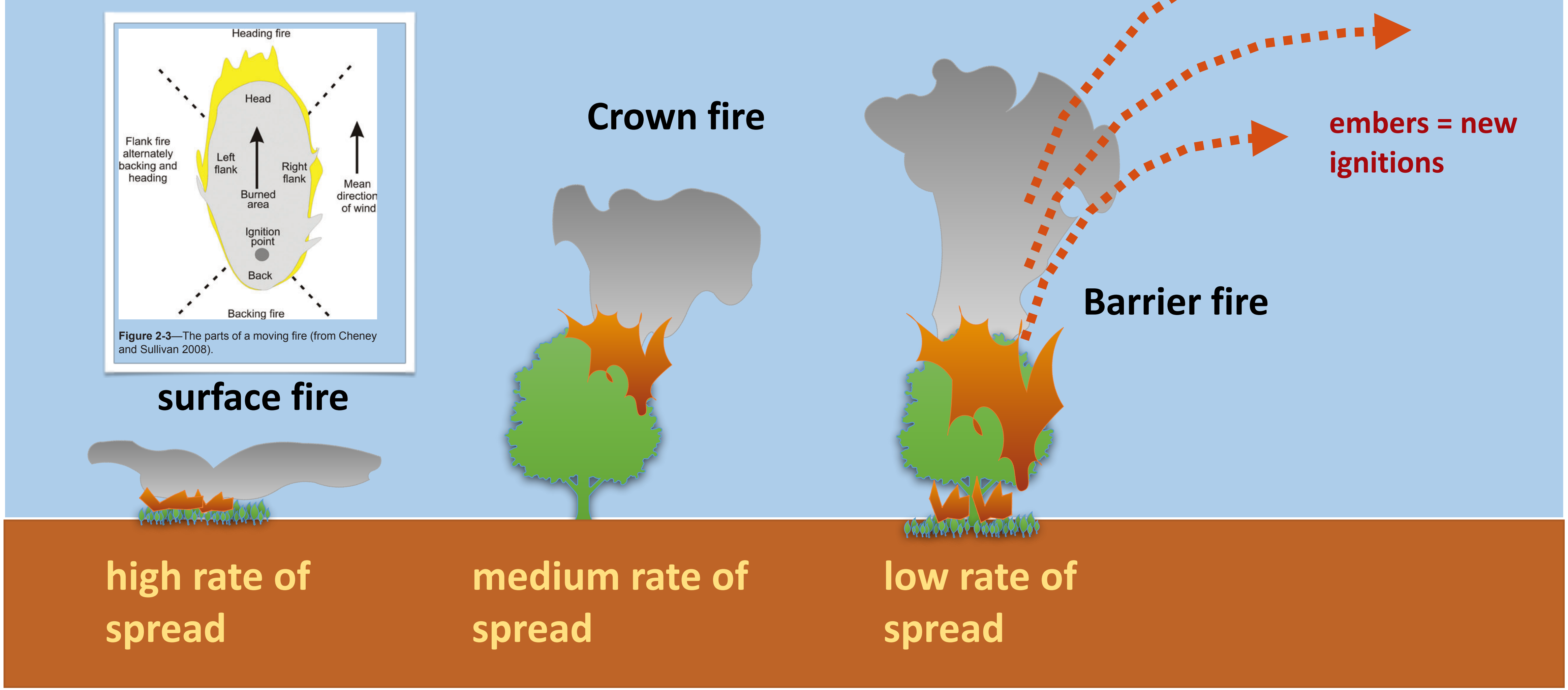
Figure 2-2—Stylized flame zone characteristics (a), combustion phases, and dominant heat transfer mechanism (b) (adapted from Rothermel 1972; Pyne and others 1996; Cochrane and Ryan 2009).

Table 2-1—Temperatures associated with phases of combustion.

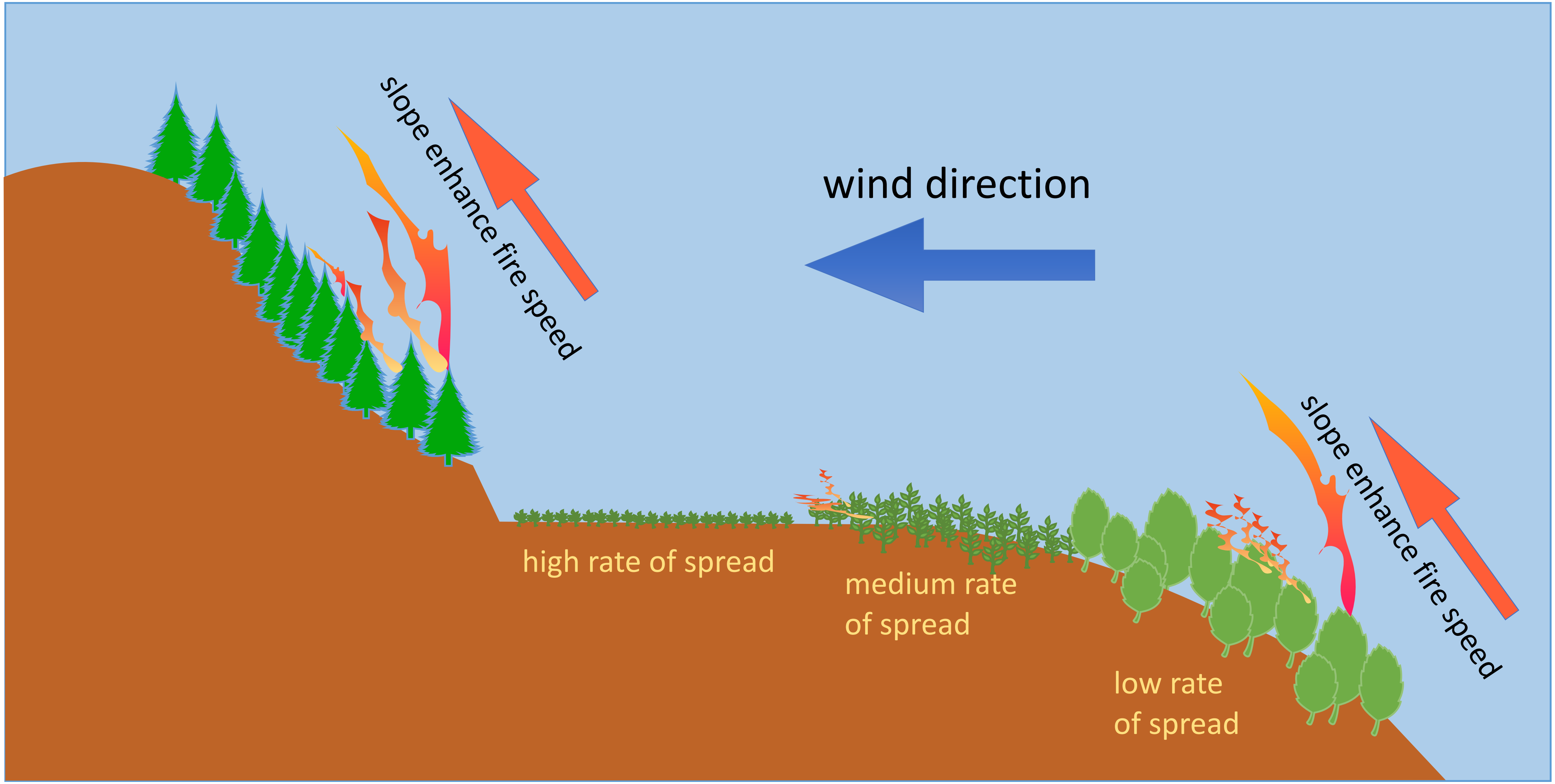
Temperature °C	Effect
0-100	Preheating of fuel: free water is evaporated
100-200	Preheating of fuel: bound water and low molecular weight compounds volatilized, decomposition of cellulose (pyrolysis) begins, solid fuel is converted into gaseous vapors
200-300	Preheating of fuel: thermal degradation continues more rapidly
300-325	Ignition temperature in well aerated wildland fuels: transition to flaming
325-400	Flaming phase: rapid increase in decomposition of solid fuel
400-500	Flaming phase: gas production rate peaks around 400 °C and declines between 450 °C and 500 °C as all residual volatile compounds are released.
500-1000	Flaming phase: Maximum flame temperatures within flames may approach 1600 °C in deep flame envelops but temperatures of 500 °C to 1000 °C are more typical.
500-800	Glowing phase: residual carbonaceous fuel (charcoal) burns by glowing combustion. The combustion of charcoal is associated with the liberation of CO and CO_2

Figure from [2]

Spreading mechanism of forest fires



Spreading mechanism of forest fires



Spreading mechanism of forest fires

factor affecting spread of forest fires:

- weather
  - wind
  - humidity
  - drought
- terrain
  - slope
  - elevation
- fuels
  - canopy
  - surface
  - ground

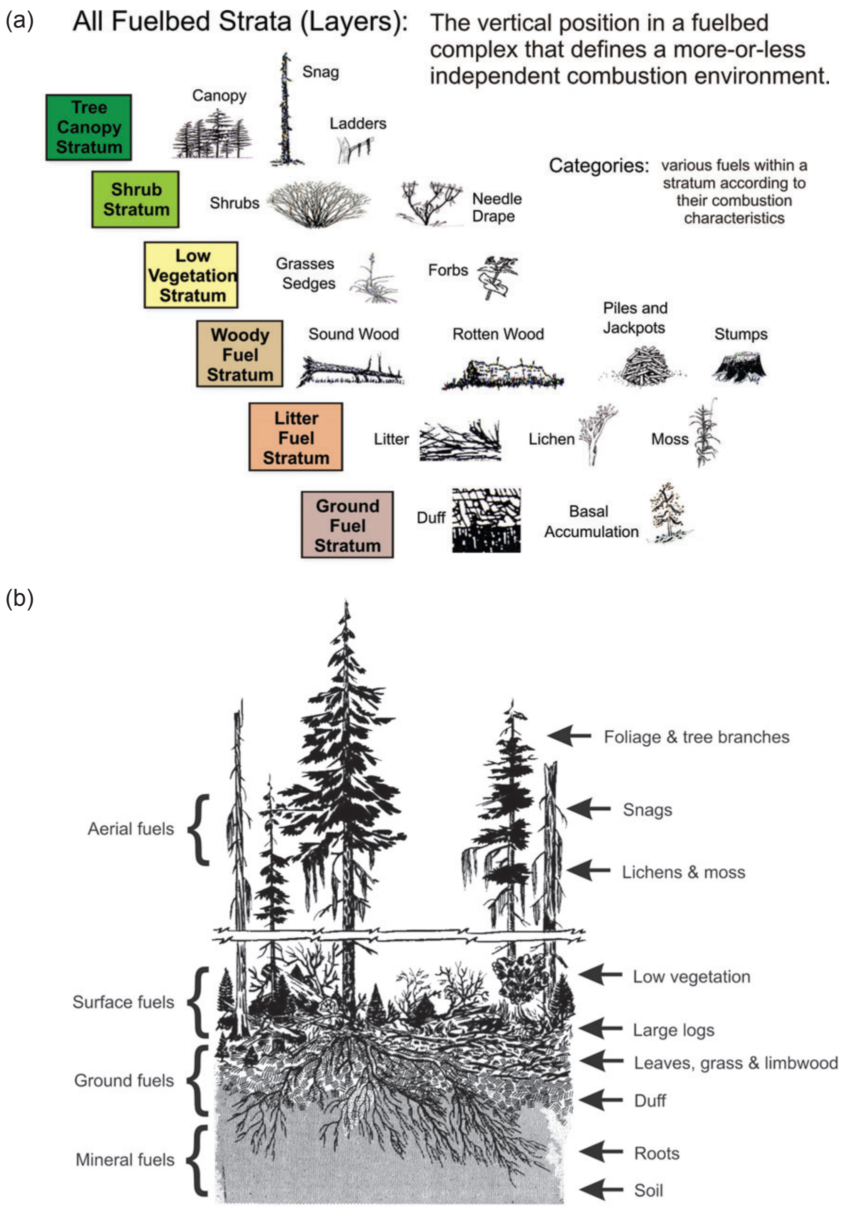


Figure 2-4—Fuel elements by stratum (a) (from Sandberg and others 2001) aggregate to make a fuel bed (b) (from Barrows 1951).

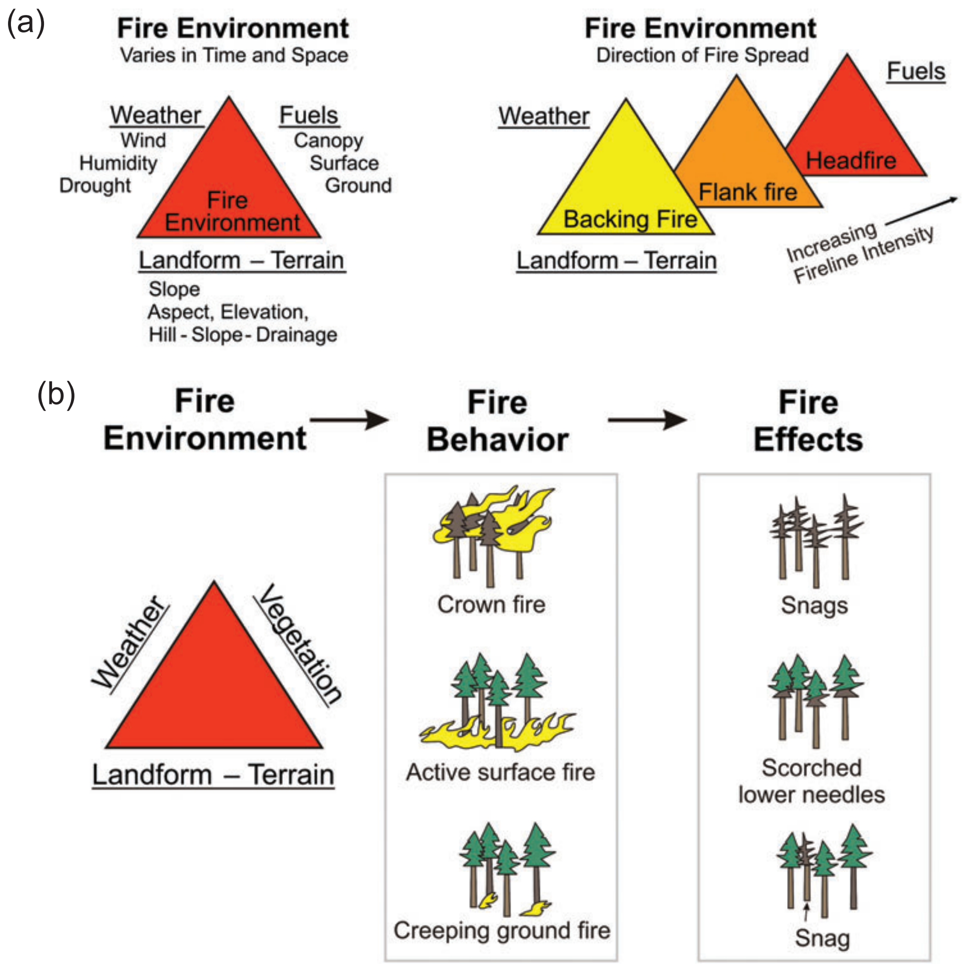
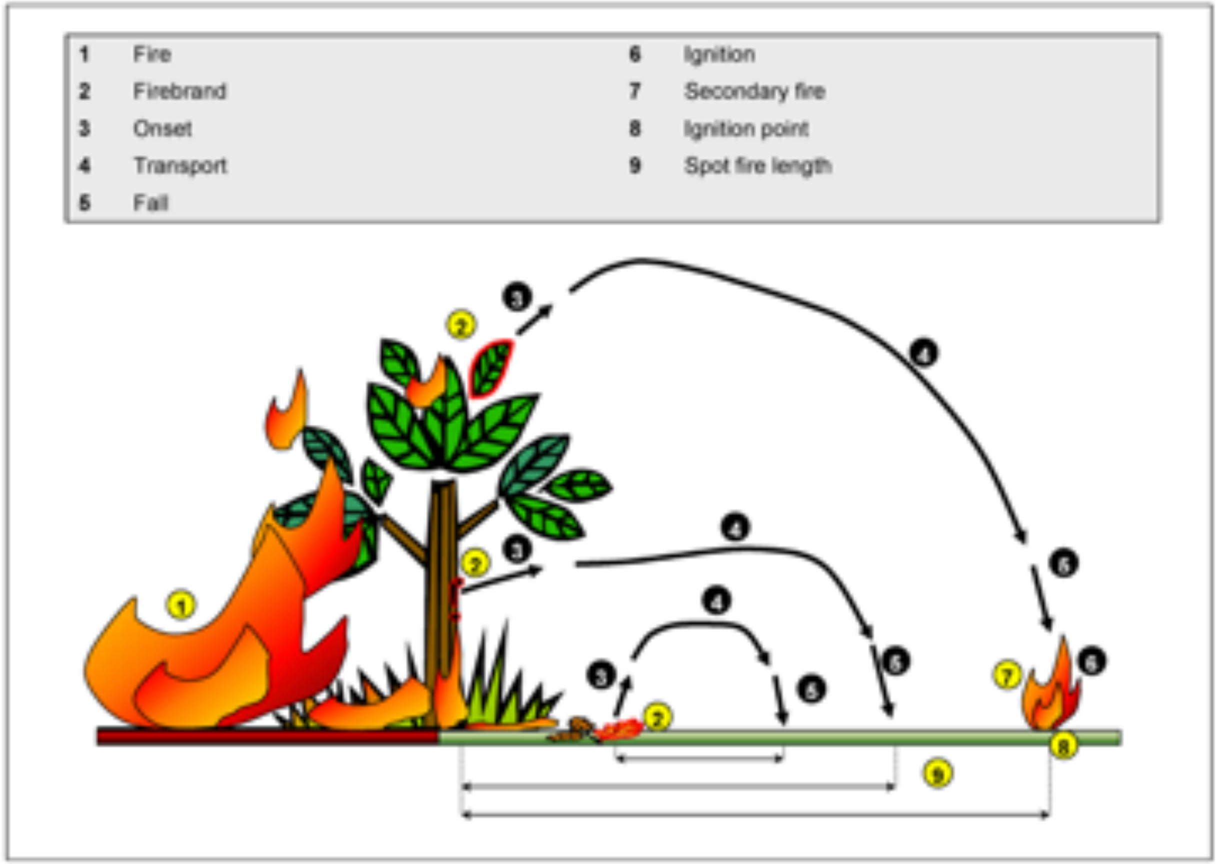


Figure 2-6—Fire environment, behavior, and effects (from Ryan 2002).

Figures from [2]

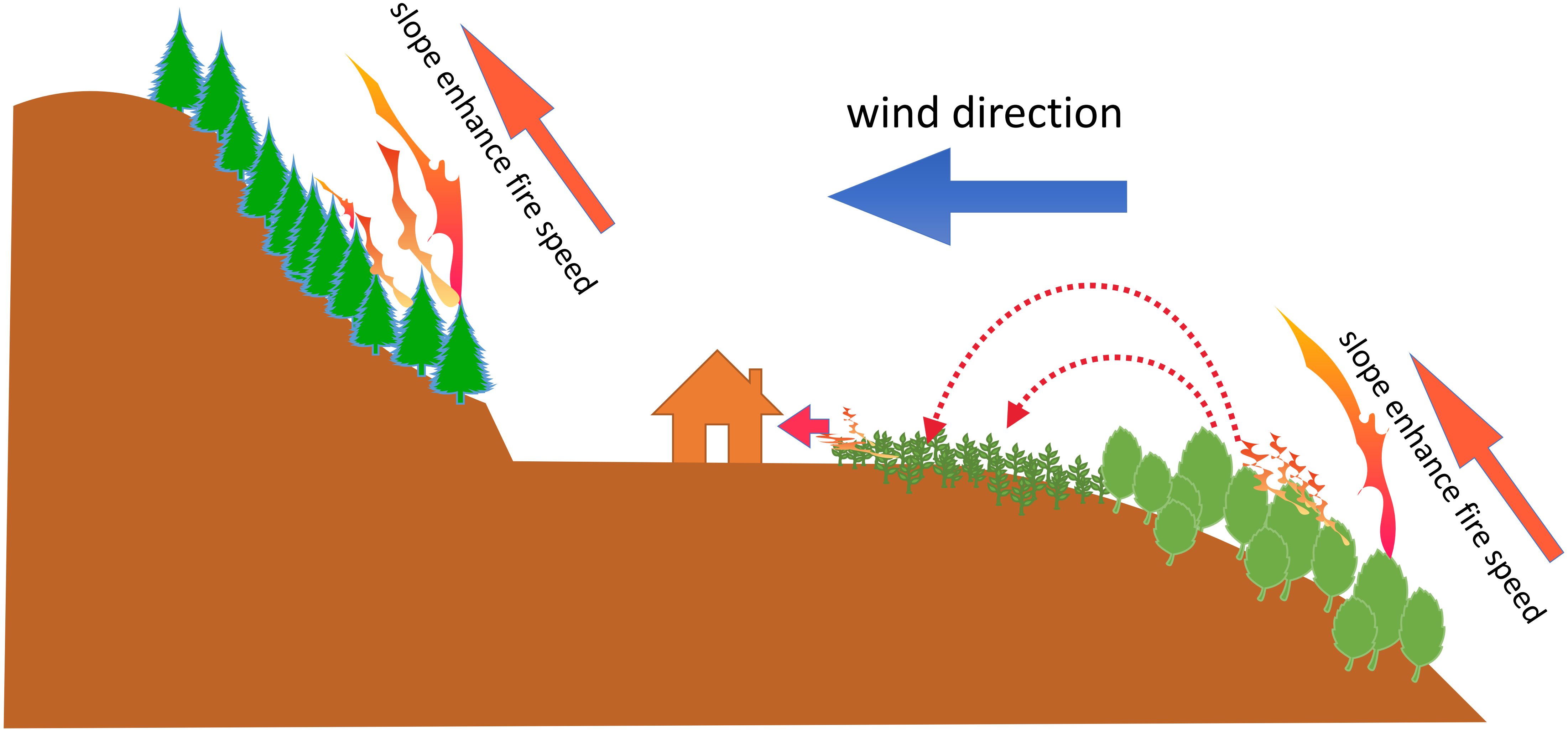
3- Spreading mechanism from forest to structural fire

Spreading mechanism from forest to structural fire



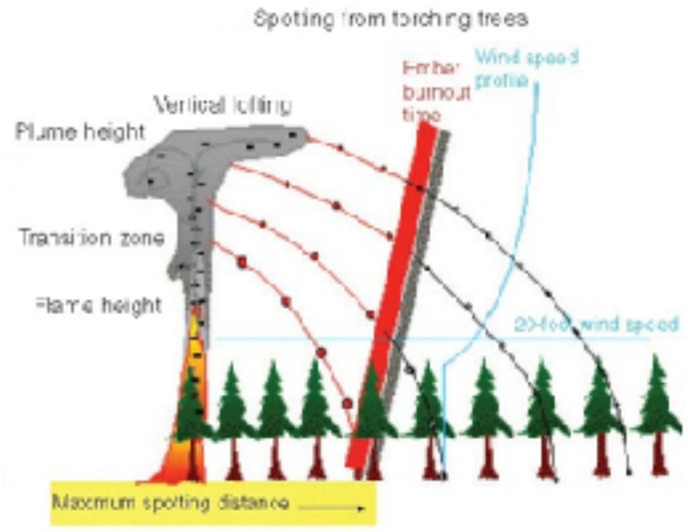
Manselli L. - Un metodo per valutare la plausibilità di un evento e applicazione alla propagazione di particelle ardenti - Ingegneria antincendio, pianificazione dell'emergenza negli incendi boschivi e di interfaccia nel sistema integrato di videosorveglianza e telerilevamento degli incendi boschivi nelle regioni Puglia e Calabria - Dipartimento dei Vigili del Fuoco, del Soccorso Pubblico e della Difesa Civile - Marzo 2014 Roma

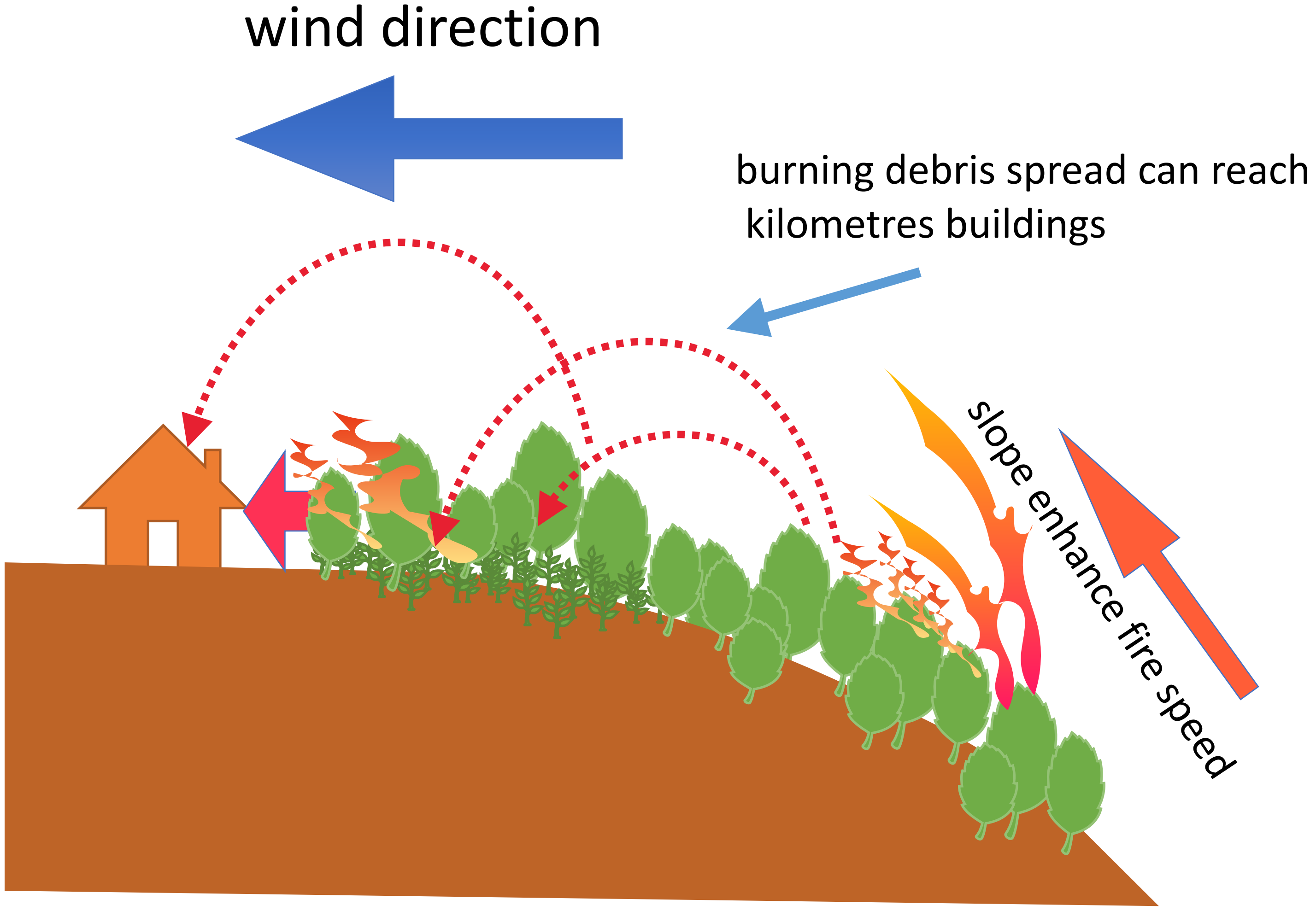
Spreading mechanism from forest to structural fire



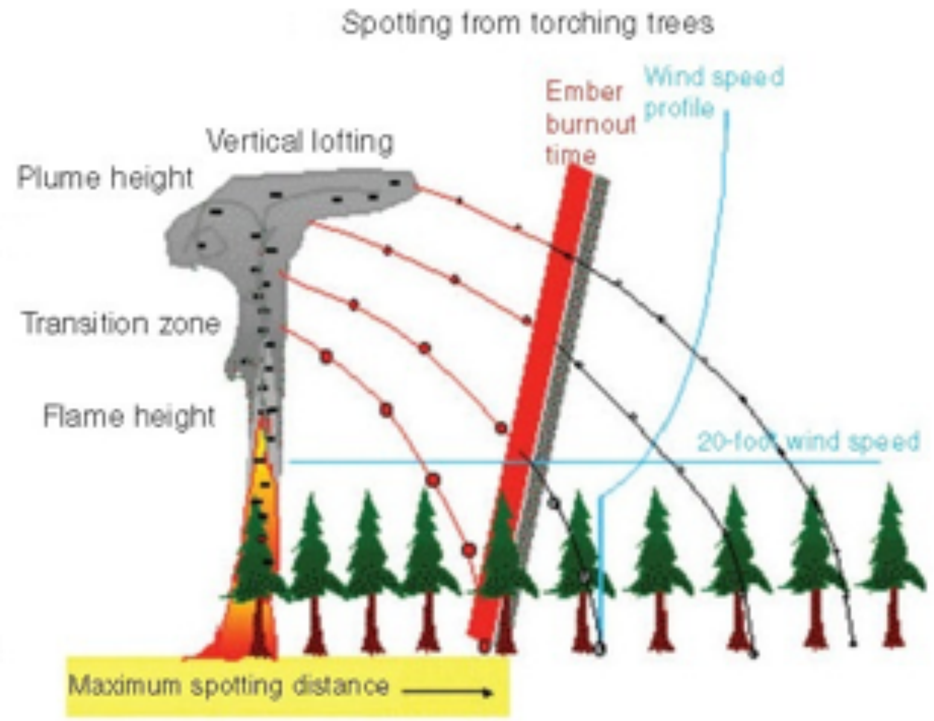
Spreading mechanism from forest to structural fire

- radiation
- embers





Spreading mechanism from forest to structural fire



$$e^{2N(h-z_0)} = \frac{1+\frac{N}{g}\,\bar{v}^{\,2}}{\cosh^2\left(\frac{D}{v_0\cos\phi} - \frac{1}{\sqrt{gN}\,\arctan\left(\sqrt{\frac{N}{g}}\,\bar{v}\right)}\right)}.$$

Manselli L. - Un metodo per valutare la plausibilità di un evento e applicazione alla propagazione di particelle ardenti - Ingegneria antincendio, pianificazione dell'emergenza negli incendi boschivi e di interfaccia nel sistema integrato di videosorveglianza e telerilevamento degli incendi boschivi nelle regioni Puglia e Calabria - Dipartimento dei Vigili del Fuoco, del Soccorso Pubblico e della Difesa Civile - Marzo 2014 Roma

Spreading mechanism from forest to structural fire

NFPA 914: Code for Fire Protection of Historic Structures

9.5.3.8.1 This scenario shall be an outside exposure fire.

9.5.3.8.2 This scenario shall address a fire that starts remotely from the area of concern and either spreads into the area, blocks escape from the area, or develops untenable conditions within the area.

4 - Effects of fire on structures (vd Nassi)

5 - Effects of vegetation fires on artefacts

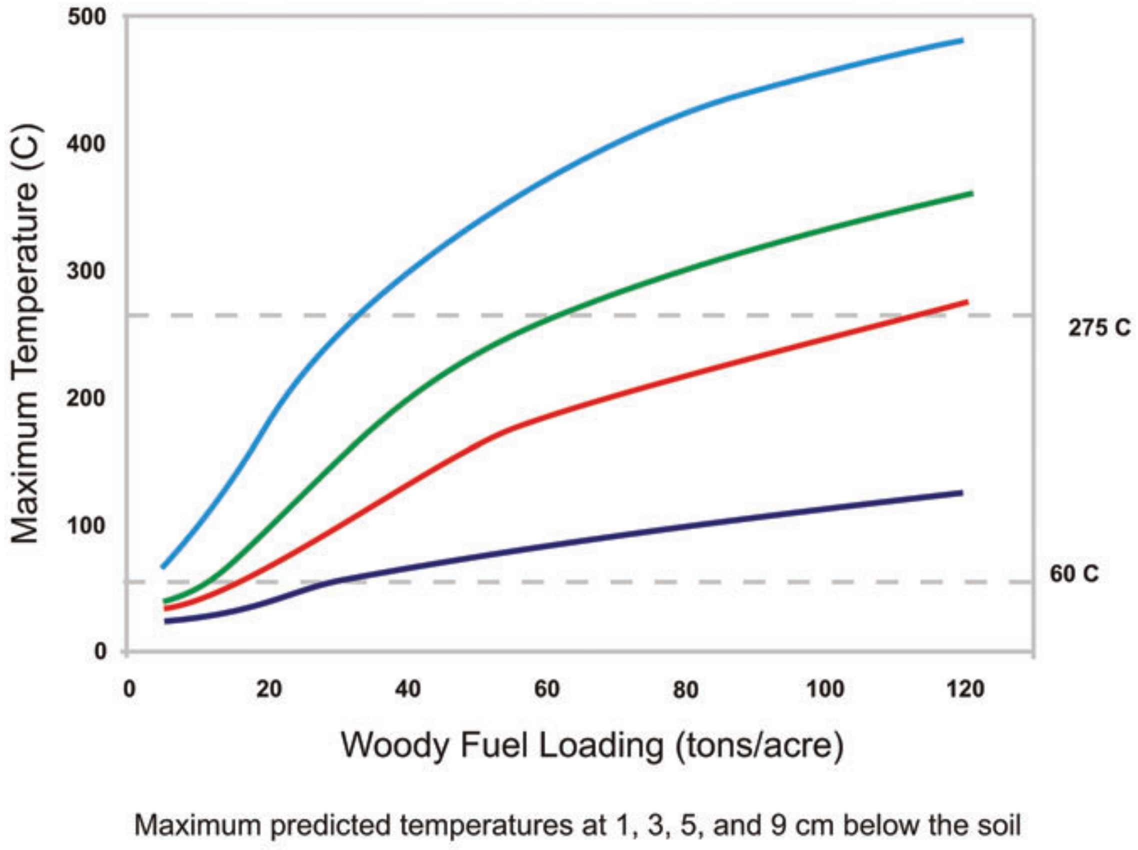


Figure 2-21—Maximum soil temperatures predicted by the soil heating model in the First Order Fire Effects Model (FOFEM) (Reinhardt and others 2005) for varying loadings of coarse woody debris (CWD (from Brown and others 2003). Solid lines depicting 1, 3, 5, and 9 cm below the soil starting from top to bottom.

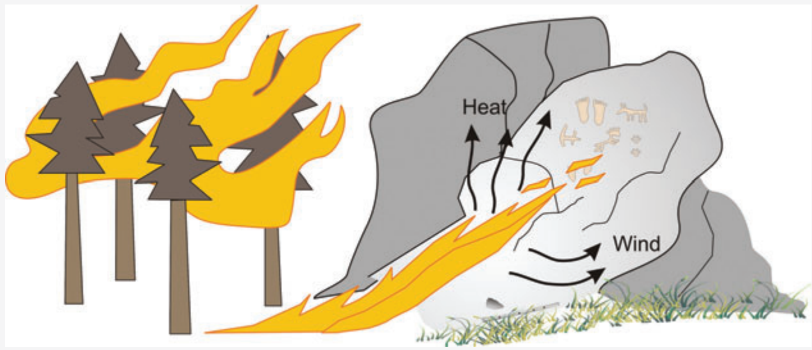


Figure S1.2. Convective and radiant heat from fires are a major source of damage to above ground cultural resources such as rock art.

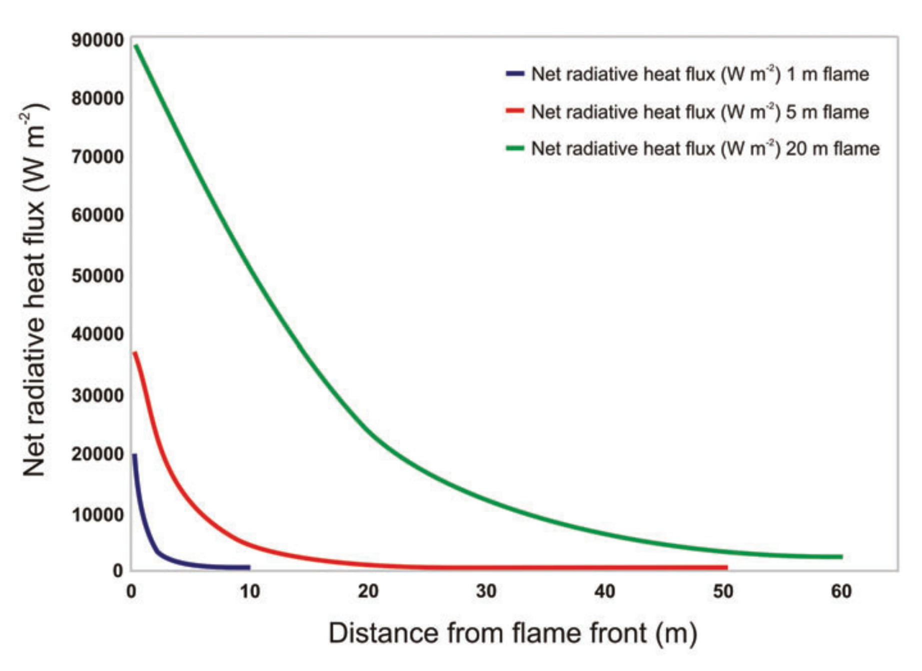


Figure S1.3. Radiant heat flux received by a rock surface or a log cabin wall decreases with distance from the flame envelope and increases with the size of the flame envelope. The more intense the fire, as exhibited by the larger the flame, the greater the distance that damage can occur.

Forest Fires and Wildland Urban Interface fires

Table 4-1—Some reported thermal effects on chert.

Temperature (°C)	Temperature (°F)	Effect [a]
150	302	Impurities may result in fractures
121 - 400	249.8 - 752	Change in interior luster
240 - 800	464 - 1472	Change in color on external surface
350 - 400	662 - 752	Becomes distorted, brittle, or explosive
350 - 550	662 - 1022	Fractures
600 - 800	1112 - 1472	Optical dulling of external surface

a Note: Cherts from different sources react differently to heat. Some effects can occur at lower temperatures if duration of heat is long enough. Not all cherts change color or luster when heated. Temperatures for other effects summarized in text are unknown, or variable from Luedtke (1992).

Surface artifacts generally suffer the most damage in fires, although many will often retain data potentials, even on sites burned numerous times in the past, or that have recently been subjected to wildfires or prescribed burns. Some lithic and ground stone scatters, as well as other types of archaeological sites, are strictly limited to surface contexts, due to shallow soils or depositional history.

…. Since even shallow soils offer some protection to artifacts, one can conclude that subsurface materials will generally retain the most data potential following wildfires. However, **the surface of a site at any given point in time can change as a result of numerous agents, including deflation, erosion, deposition, windthrown trees, animal burrowing and human activities**.

Fire Effects on Pottery

Vessel- forming techniques could be combined in a number of ways. For example, a vessel's base could be molded while its walls were formed with coils. The way in which pottery was made may affect how it is altered by fire.

Fire's impact on pottery decoration is of concern to archaeologists who use decorative design as a criterion for identifying potsherds. This impact of fire can vary according to the way in which clay vessels have been decorated.

Fire Effects on Flaked Stone, Ground Stone, and Other Stone Artifacts

Reported fire effects on stone artifacts include breakage, spalling, crenulating, crazing, potlidding, microfracturing, pitting, bubbling, bloating, smudging, discoloration, adhesions, altered hydration, altered protein residue, and weight and density loss. Surface artifacts tend to be altered more than those located in subsurface contexts, with protection often afforded by even a few centimeters of soil.

Basalt

Lentz (1996a) noted sooting, potlidding, oxidation, reduction, crazing, luster changes, and adhesions on lithic material, including basalt that had been in a wildfire. Eisler and others (1978) found basalt to be covered with a shiny, smooth, tar-like, brittle residue, with basalt boulders fractured into angular chunks, possibly due to rapid cooling. Tremaine and Jackson (1995) reported thermal fractures on basalt bifaces.

Ground Stone

ob- jects manufactured of different materials will react differently to heating and cooling. For instance, Pilles (1984) reported sandstone manos that were severely cracked in wildfires, where basalt manos were only blackened. Lentz (1996) indicated that all five metates in a wildfire were affected by sooting, spalling, dis- coloration and/or adhesions, but the single mano was not altered.

Based on field observations and experiments, Blackwelder (1927) concluded that in many forested areas of the western United States, fire was the primary agent of fracturing, spalling, and weathering in boulders and rock outcrops, rather than diurnal changes in tempera- ture.

Implications for Cultural Resource Protection and Fire Planning

The key factors that seem to affect the nature and extent of fire damage to archaeological resources, including lithic artifacts, are fire intensity, duration of heat, and penetration of heat into soil (Traylor and others 1983). Research shows that as temperatures increase, so do effects, and that effects increase as the length of time exposed to heat increases; if exposure time is long enough, effects can occur to stone tools even at reduced temperatures. Buenger's fire simula- tions show that the two most important components of the fire environment resulting in thermal effects to surface artifacts are fuel loads and wind velocity (2003)

Figure S1.1. Spalling of rock art following the 2003 Hammond Fire, Manti LaSal NF, Utah (Johnson 2004). Pictograph damaged by heat from forest fire (photo Clay Johnson, Ashley NF).

Figure 5-5—Spalling and exfoliation caused by fires. Top: Spalling of rock art following the 2003 Hammond Fire, Manti LaSal NF, Utah (Johnson 2004). Pictograph damaged by heat from forest fire (photo Clay Johnson, Ashley NF). Bottom: Typical exfoliation of granitic rock where fuels are nearby and burning very hot. No cultural features were affected.

Figure S1.1. Spalling of rock art following the 2003 Hammond Fire, Manti LaSal NF, Utah (Johnson 2004). Pictograph damaged by heat from forest fire (photo Clay Johnson, Ashley NF).

Fire Effects on Rock Images and Similar Cultural Resources

Rock shelters, overhangs, and vertical rock faces containing rock image panels may suffer two types of damage from wildland fires: thermal effects from energy (heat) absorbed and depositional damage from exposure to smoke, soot, ash, smudging, and tars as combustion products. The energy may result from either radiation or convection but higher temperatures are associated with the former. Common results are discoloration, exfoliation or spalling, and heat absorption

Common results are **discoloration, exfoliation or spalling,** and heat absorption (fig. 5-5). Smudging occurs when combustion products precipitate on or adhere to exposed rock surfaces. Chemical and physical changes are probably caused by heat penetration and charring of organic pigment binder materials of painted elements

Fire Effects on historic building materials

Susceptibility to Fire: Low-fired, relatively porous firebrick, which is typical of non-commercial, locally made brick used at many historical sites, can weaken and crumble if the fire is hot enough. Lime-based mortar can be affected by fire. It can calcinate and crumble under sufficient heat, thereby loosening the firebrick and, if not replaced, causing the brick wall to eventually collapse. Cinder block and masonry surfaces may spall, which appears as distinct lines of striation and loss of surface material resulting in cracking, breaking, chipping, and formation of craters on the surface.

Miscellaneous Artifacts

• *Leather* is a material that is sometimes found on the surface of historic sites. Such objects as shoes, belts and horse tack become dry and brittle over time. Leather will char in a grass fire, and will be completely consumed at hotter temperatures.

• *Rubber* and *rubberized objects* are present on many historic sites, some dating to the Civil War period and even earlier. Rubber can be ignited and completely consumed at low temperatures such as those reached by grass fires.

- *Plastics can appear on historic sites that date to the early 20th century, but is most common after circa 1950. Plastics have been used to manufacture a wide variety of objects such as toys, buttons, tool handles, and containers. Various plastics have varying melting points but most plastic objects would be affected to some degree by a low temperature fire.*
- Of course, artifacts made of wood are quite common on historic sites, and can include everything from buckboards and Model T car seat frames, to ox yokes and axe handles. When present on a site and in the open they usually have some rot, increasing their susceptibility to destruction by fire.
- Bone, especially if dry and porous, will char in a grass fire, and will be completely consumed in a high temperature fire.
- Shell buttons will become discolored, flake and split laterally along the laminations, and eventually turn to powder if subjected to a high temperature fire. This will also occur at lower temperatures if the buttons are very small and thin.

5 - Effects of fire on intangible cultural heritage

6 - Damage caused by fire suppression and rehabilitation

The indirect effects of fire include exposure of surface **cultural properties to erosion and to increased visibility**. The removal of vegetation and surface litter can expose cultural properties formerly not readily visible to the eye, **therefore making them more vulnerable to looting**. **Post-fire erosion on steep slopes** of severely burned areas can occur after intense wildland fires have destroyed most of the pre-fire vegetative canopy, causing the horizontal displacement of surface cultural materials. A fire can leave standing **vegetation that becomes vulnerable to blow down** and can impact both surface and subsurface cultural properties.

Cultural resources **may be affected directly by suppression activities** (hand and mechanical fire line construction, retardant use) and **rehabilitation activities**.

It is generally concluded that fire **suppression activities** during wildland fires and post-fire site rehabilitation treatments **present the most consistent adverse impacts and pose the greatest risk** to cultural properties.

7 - Conclusions

- the increasing risk of forest/vegetation fires pose a greater risk to CR;
- the risk is posed by fire, by fire suppression activities and by rehabilitation;
- the increased visibility of CR after a fire poses a problem of possible looting;
- literature shows that response to mitigate the effects of vegetation fire to CR is a complex strategy composed by training, adoption of protection measures and organisation.

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- USDA Forest Service. (n.d.). Wildland Fire in Ecosystems Effects of Fire on Cultural Resources and Archaeology. Retrieved from http://www.fs.fed.us/rmrs

Thank you

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