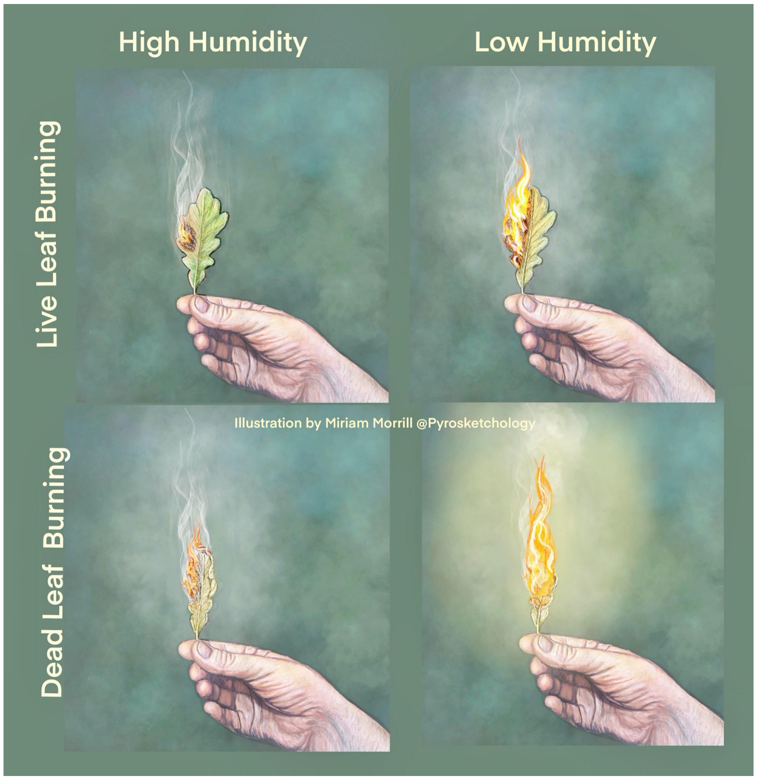
6- PLANT MOISTURE & FIRE COMBUSTION (FIRE TRIANGLE)



INTRODUCTION

Students review basics (observable aspects) of the fire triangle and how that relates to fuel moisture, humidity, and vapor pressure deficit and what that means for fire ignition and spread. Students will gather live and dead vegetation elements (grasses, leaves, etc) using a comparison table to study differences in plant moisture using hearing, sight, smell, and touch. The teacher uses plant materials for an ignition and burning experiment that students observe and journal. Students will choose one of their live/dead vegetation observations and sketch the shapes on their story zine, adding key descriptive words and phrases that differentiate between the live and dead plant elements. Students then add a few notes on thoughts relative to fire ignition and spread based on plant moisture.

LESSON OVERVIEW & ESTIMATED TIME (60 MINUTES)

- Teacher introduction to lesson **(2 minutes)**
- Teacher discussion of the fire triangle, fuel size (surface area to volume) and dead fuel moisture lag time **(10 minutes)**
- Teacher discusses field safety **(3 minutes)**
- Teacher and or students gather live and dead vegetation materials (grasses, leaves, etc.) and come back as a group **(5 minutes)**
- Teacher provides weather metadata and demos and facilitates student creation of the comparison table facilitating discussion and journaling the sensory observations **(15 minutes)**
- Teacher overview of live fuel moisture considerations such as the vapor pressure deficit and what that means for fire ignition and spread **(5 minutes)**
- Teacher uses live and dead leaf materials to compare ignition and burning with different moisture levels **(10 minutes)**
- Teacher demo and students follow sketching and adding key words and or phrases from the comparison table onto the zine page **(10 minutes)**

MATERIALS & RESOURCES

- Journal or notebook
- Printed formatted story zine
- Graphite pencils, erasers, and optional colored pencils or water colors with paint brush
- Optional rulers or measure tapes
- Optional gloves and clippers or scissors, if needed to cut leaves or grasses
- Collected local leaves and grasses
- Plastic tube or large bucket with sand or water. Sand would allow dropping burning leaves and observing any additional burning,, but that is not crucial to the key part of the observation.
- Lighter and or large wooden matches. Matches are a nice approach to limit burning time and heat intensity in a visual way.
- Weather metadata for the day/time of plant collection and observations (temperature and humidity)

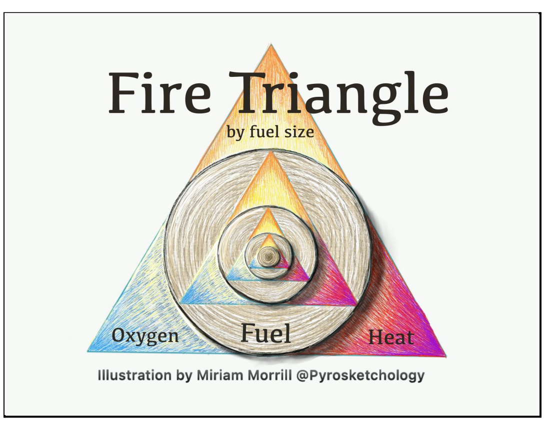
LOCATION

This exercise can be done indoors but is recommended to be outdoors for at least part of the session such as collecting plant materials. If no live and dead grass or leaves are accessible at the location, the teacher should collect materials prior to the session. The burning demonstration should be in an area free of vegetation and protected from winds. Most of this lesson will be completed as a group so a comfortable area for students to sit, observe and discuss is ideal.

BACKGROUND & NATURAL PHENOMENA INVESTIGATED

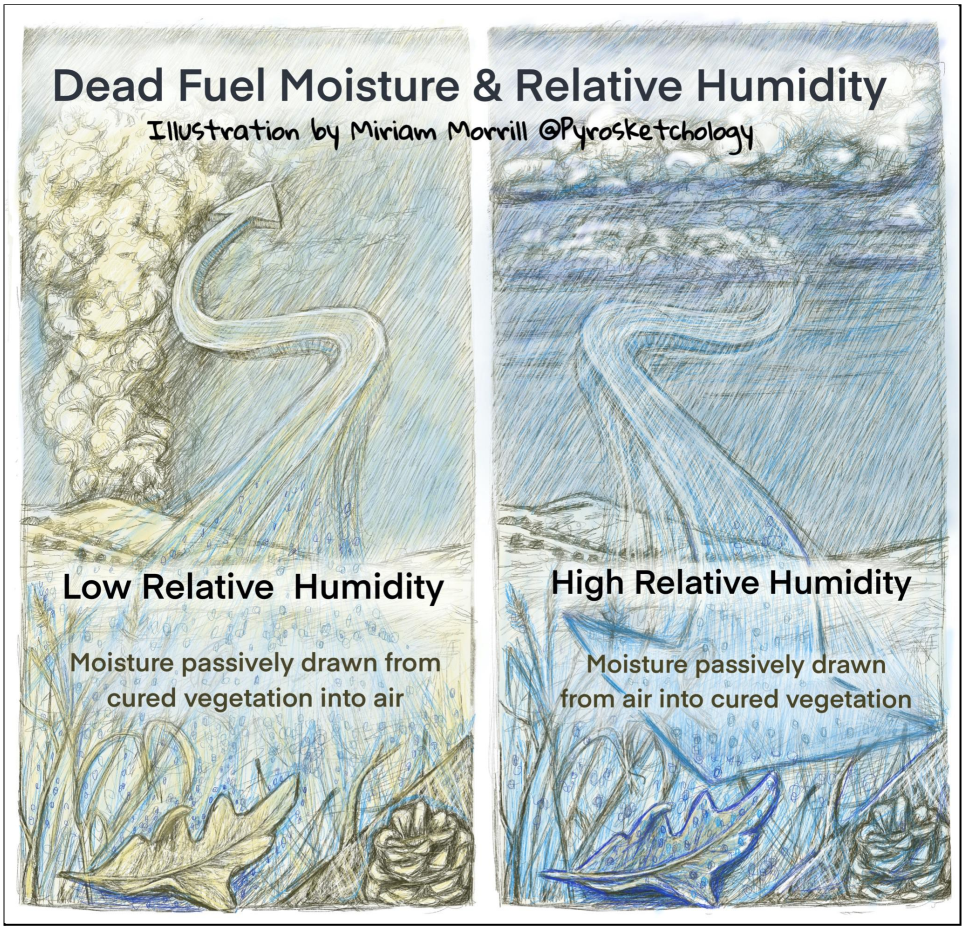
The influences of weather phenomena on vegetation is crucial to understanding fire ignition and spread. As learned in the weather and fire lesson, weather events and patterns occur as a result of one or a combination of the water cycle, atmospheric pressure systems, and the Coriolis effect. The photosynthesis process and phenological phases of plants are associated with the weather and influences the ignitability and spread of fire. The primary focus in this lesson is observing and sensing the moisture differences in live vegetation from vapor pressure deficit process and moisture in dead plant materials from the relative humidity in the atmosphere. This lesson emphasizes sensory engagement skills and observations intended to create a deeper sense and awareness of changing vegetation conditions and fire behavior.

LESSON INTRODUCTION FOR STUDENTS (2 Minutes)



In this lesson we will learn about how moisture in the air and in live and dead plants can influence fire ignition and spread. We'll start with a review of the fire triangle and how that relates to moisture influences on plants and fire. We'll be using our senses to make observations about plant materials and we will have a live fire demonstration with a few small plant materials to see if there are differences in how these materials ignite and burn.

REVIEW PLANT MOISTURE AND THE FIRE TRIANGLE (10 Minutes)



- Gather students into a group and explain how the fire triangle is framed around the three primary ingredients needed for fire to occur. Ask if anyone knows what those three elements are?

  Discussion: The fire triangle includes oxygen, fuel and heat and represents the combustion process. From an observation aspect, the fire triangle can be a little abstract, but if you also consider that the triangle symbol in math and chemistry represents a change in form or a chemical reaction it can be a little more representational. In Ancient Greek fire is represented as a triangle and symbolizes a desire to ascend, with the top pointing upward.

- Ask students if they have any idea of what the ascending aspect of fire might be referencing.

  Discussion: Fire (combustion process), on the landscape, is changing the form of solid carbon (vegetation) into a gas, which is propelled into the atmosphere or ascending into the sky.. In the above concept illustration of the fire triangle, the triangle is used to represent the change in form but the three elements are not equal and opposing along the edges. Fuel (vegetation) is the central element that is being transformed when meeting with the elements of oxygen and heat. The tip of the triangle represents the flame coming from the reaction. There are smaller fire triangles embedded within the larger one, to represent that with a change in the size of fuel, the amount of oxygen and heat also changes. More on that with the next illustration.

- Ask students if they can think of a natural process that is the opposite of combustion. What process takes in carbon as a gas, using oxygen (air) and heat (sun) to create a solid carbon form?

  Discussion: Photosynthesis is nearly an opposite process to combustion. Combustion is a quick reaction whereas photosynthesis is a slower process occurring within a plant but photosynthesis breathes in carbon dioxide, using oxygen and the sun to help build plant tissue (solid carbon). Fire, in a way, breathes too. It inhales oxygen and exhales carbon dioxide. Plants inhale carbon dioxide and exhale oxygen. In many ways, plants are a product of the sky, and connected to the earth.

- Ask students if they know why moisture influences the fire triangle and combustion process.

  Discussion: Most people know that water cools and extinguishes a fire- reduces/removes oxygen to fire, but the amount of moisture in a plant changes how easily vegetation can ignite, burn. Both living and dead plants can have changing levels of moisture that are very important in understanding the fire environment and level of fire ignition and spread risk. In fire management, experts use different metrics to estimate live and dead vegetation (fuel) moisture.

- Ask students if they have ideas about how dead vegetation like fallen leaves, dry grass, pine cones and fallen branches can gain and lose moisture.

  Discussion: Rain is easy to relate to dead vegetation moisture and limited fire ignition, but there is something more important that fire specialists look at- something that changes throughout the day and the year. Air moisture or relative humidity levels have a strong influence on dead vegetation moisture and combustibility. **Humidity** is the concentration of water vapor (gas form of water) present in the air. The level of humidity depends on the temperature and atmospheric pressure. **Relative humidity** tells us how much water vapor is in the air, compared to how much it could hold at that temperature before it becomes saturated and produces rain. It is shown as a percent. Relative humidity is also used to measure moisture levels in dead vegetation to assess ignitability and potential fire spread. A low relative humidity means dry conditions and less water vapor in the air.

  - Explain to students that In fire management, dead fuel moisture is measured by several fuel size categories (volume) based on the time lag it will take for ⅔ of the dead fuel to respond to the relative humidity. (10–hour, 100–hour, or 1,000–hour). A large leaf may have a big surface area but small volume. Consider how oxygen, moisture or heat needs to travel further through a larger volume and thus the longer lag time to equalize with the air moisture. For example, it takes 1 to 10 hours for the smallest vegetation materials to dry or moisten to the level of atmospheric moisture (relative humidity). Fire practitioners have wood rods measured and weighed for 1 to 1,000 hour fuel models. These fuel moisture sticks are placed outside at a weather station and used to estimate fire ignition potential, but anyone can observe some of the vegetation moisture conditions and make helpful estimates on fire ignition and spread.

- Review with students the Dead Vegetation Moisture & Ignitability illustration below discussing the size (volume) categories and time lag. Students will need to use this information for their field exercise.

SAFETY TALK (3 minutes)

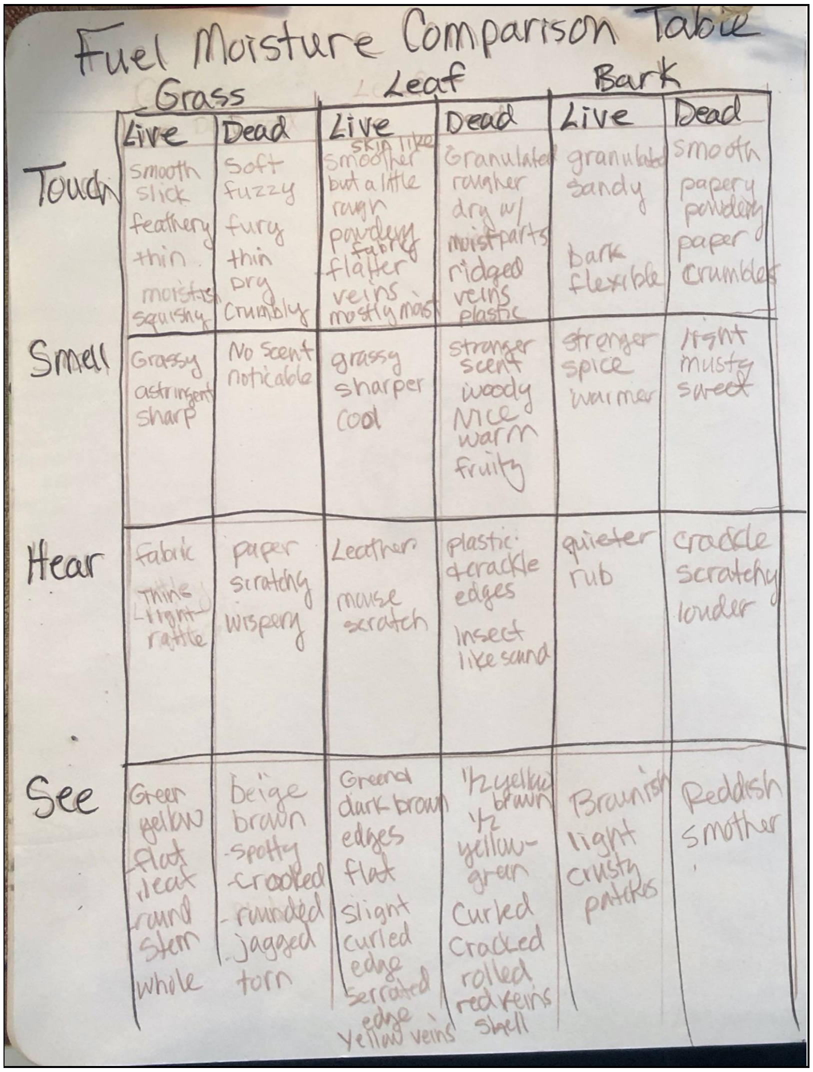
- Give safety talk appropriate to location and conditions. See guide introduction section with Safety Discussion overview.
    - Collecting plant materials that are safe to handle and avoiding potential skin irritation or cuts
- Fire safety when igniting and burning plant materials for demonstration. Be in an area more sheltered from the wind and away from dry vegetation. Have water available either in a bucket or a bottle of water over a sandbox to fully drown burning materials.
- Sensory observations of touching and smelling could have some potential allergy reactions so students with health risks may rely on the input of others from the group sensory discussions.

EXERCISE: GATHER LIVE AND DEAD FUELS (5 Minutes)

- In this exercise, the teacher and students will gather and journal sensory observations of live and dead fuels/vegetation and consider fuel size (surface area to volume), shape, and current moisture conditions. The teacher can guide students in gathering a mix of live and dead grasses, leaves and other small fallen vegetation materials (could include acorns, cones, bark strips, small branches) or direct students to gather with safety considerations. Ideally, the live and dead vegetation should be from the same or similar size and shaped plants to better compare moisture differences.

- The intent with this exercise is to build multi-sense observation skills around vegetation conditions that can inform you of fire conditions. This can form an environmental awareness and also be used as a fire practitioner when assessing best prescribed burning conditions.

EXERCISE: CREATE COMPARISON TABLE & COMPARE LIVE & DEAD FUELS (15 Minutes)



Fuel Moisture Comparison Table

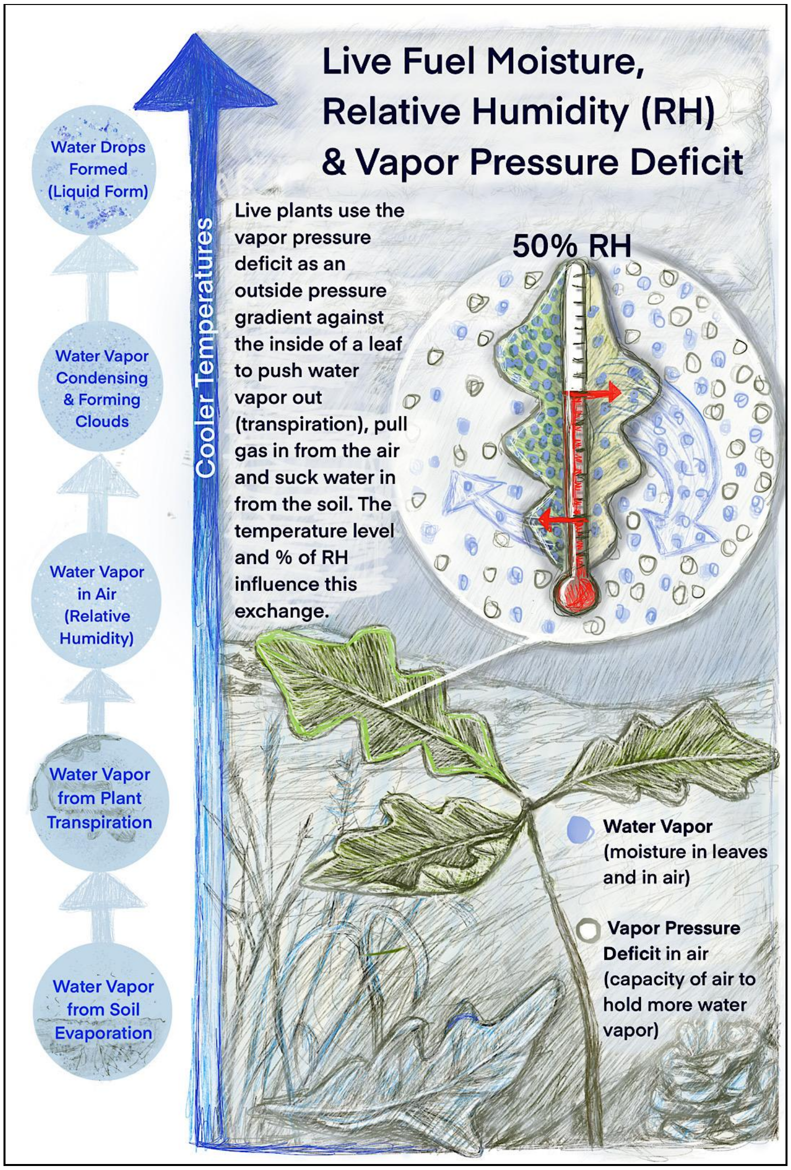
	Grass Live	Grass Dead	Leaf Live	Leaf Dead	Bark Live	Bark Dead
Touch	smooth slick feathery thin moistish squishy	soft fuzzy fury thin dry crumbly	skin like smoother but a little rough powdery fabric flatter veins mostly moist	Granulated rougher dry w/ moist parts ridged veins plastic	granulated sandy bark flexible	smooth papery powdery paper crumbles
Smell	Grassy astringent sharp	No scent noticable	grassy sharper cool	stronger scent woody nice warm fruity	stronger spice warmer	light musty sweet
Hear	fabric thin light rattle	paper scratchy wispery	Leather mouse scratch	plastic & crackle edges insect like sound	quieter rub	crackle scratchy louder
See	Green yellow flat leaf round stem whole	Beige brown spotty crooked rounded jagged torn	Green and dark brown edges flat slight curled edge serrated edge yellow veins	1/2 yellow brown 1/2 yellow-green curled cracked rolled red veins shell	Brownish light crusty patches	Reddish smother

- In the nature journal/sketchbook, create a comparison table with two to three columns for the different fuel sizes or types (grasses, leaves, etc.). Split each fuel column into a live and dead plant column.
- Create a row for the sensory categories of Touch (texture, thickness, softness, etc.), Smell, Hear (while bending, curling or rolling in hand), and See (colors, patterns, shape, etc.).
- Make sensory comparisons for the live and dead fuels using words and phrases. This can be very creative with made-up words and comparisons to anything that relates to sensory observation...smells like a wet dog, etc.
- Discuss as a group the moisture observation differences and the current relative humidity
- Save a live and dead leaf for the zine exercise.

REVIEW LIVE PLANT MOISTURE & THE VAPOR PRESSURE DEFICIT PROCESS (5 Minutes)

- Discuss: We learned a little about the dead fuel moisture influenced by the relative humidity. Live plants manage the amount of moisture within their cells through the process of transpiration.
- The transpiration process is driven by what scientists call the vapor pressure deficit (VPD). Water vapor content in the air or within a leaf can be measured as pressure (part of total air pressure). The VPD is how the plant feels specific to the location (exposure to sun) and weather conditions and is the major force moving water vapor out of the leaf based on the pressure difference between water vapor inside the leaf and water vapor outside the leaf. If there is adequate moisture in the soil and ground, plants can better maintain their temperature and manage the transpiration process when the VPD is high (higher temperatures).

- There is a complex process behind VPD and other key terms to learn but what is key for our purposes is to understand that higher air temperatures create a higher VDP and thirstier air. Even with the same amount of rain, warmer temperatures pull more water into the air (evaporative demand) and makes less available within the ground and for plants. If there is enough water in the soil and ground like in tropical areas, plants can manage their transpiration process. When the VPD is high and there is little to no water in the ground, plants shutdown their transpiration process and can starve to death. Higher temperatures, with limited moisture available.can also mean plants cannot cool themselves and can scorch leaves and even die. Understanding the connections between temperature, moisture and plants is crucial to fire awareness and climate change resilience.



- Another thing to note about relative humidity and VPD is that plants have different needs and functions during their development and phenology phases that are strongly influenced by different temperature and moisture conditions. See the Live Fuel Moisture, Relative Humidity and Vapor Pressure Deficit illustration and attached table below and discuss with students.

EXERCISE: BURNING LIVE & DEAD LEAF OBSERVATIONS (10 Minutes)

- Teacher assembles the fire safe tube or bucket with water and vegetation materials collected earlier with lighter or matches (wooden matches recommended).

- Students gathered around where they can observe the teacher demonstration.

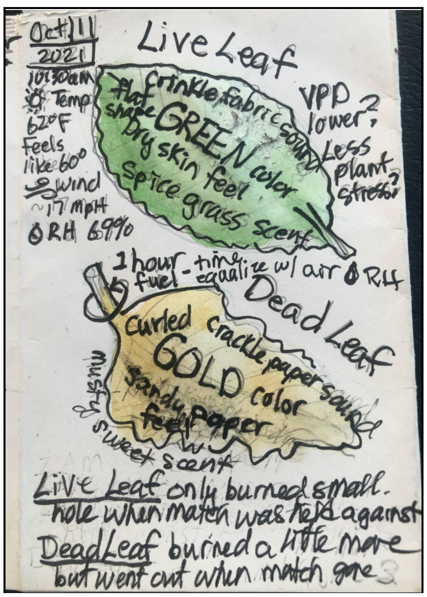
- Explain to students that they will need a pencil or pen and a page in their journal next to the comparison table, to add their observations during the demonstration.
- Teacher starts with the live grass or leaf and holds a lit match up to the lower edge of leaf/grass (room on leaf/grass to see if flame grows to tip) until the material lights or the

match burns out. Follow the same approach with the matching dead leaf/grass.

- Ask students what they observed with the live and dead leaf/grass burned.

- Ask students to discuss and write in their journal what moisture assumptions and or questions they have about the live and dead materials burned.
    - Observation review: Was there smoke? How much smoke and what color was it? White colored smoke often means more moisture (steam) and incomplete combustion. Was there a flame? How long was the flame? What color was the flame? If no flame occurred, was there any drying of the leaf by the heat source (the pyrolysis or prefire phase is a warming and drying but no flame or combustion)? A longer flame means better combustion and likely more oxygen in the vegetation (drier) and likely dryer air conditions. Was the leaf/grass fully burned or was there any material remaining? What color was the burned area and how much material was remaining? When the vegetation is completely consumed it is usually smaller in size and drier or the heat was held to the area longer (fire triangle). A black sooty area is a sign of incomplete combustion and can be a sign of higher moisture levels in vegetation and or air and also larger or more solid volume of the materials and or less combustible materials.

EXERCISE: LIVE & DEAD LEAF COMPARISON SUMMARY ON ZINE (10 Minutes)

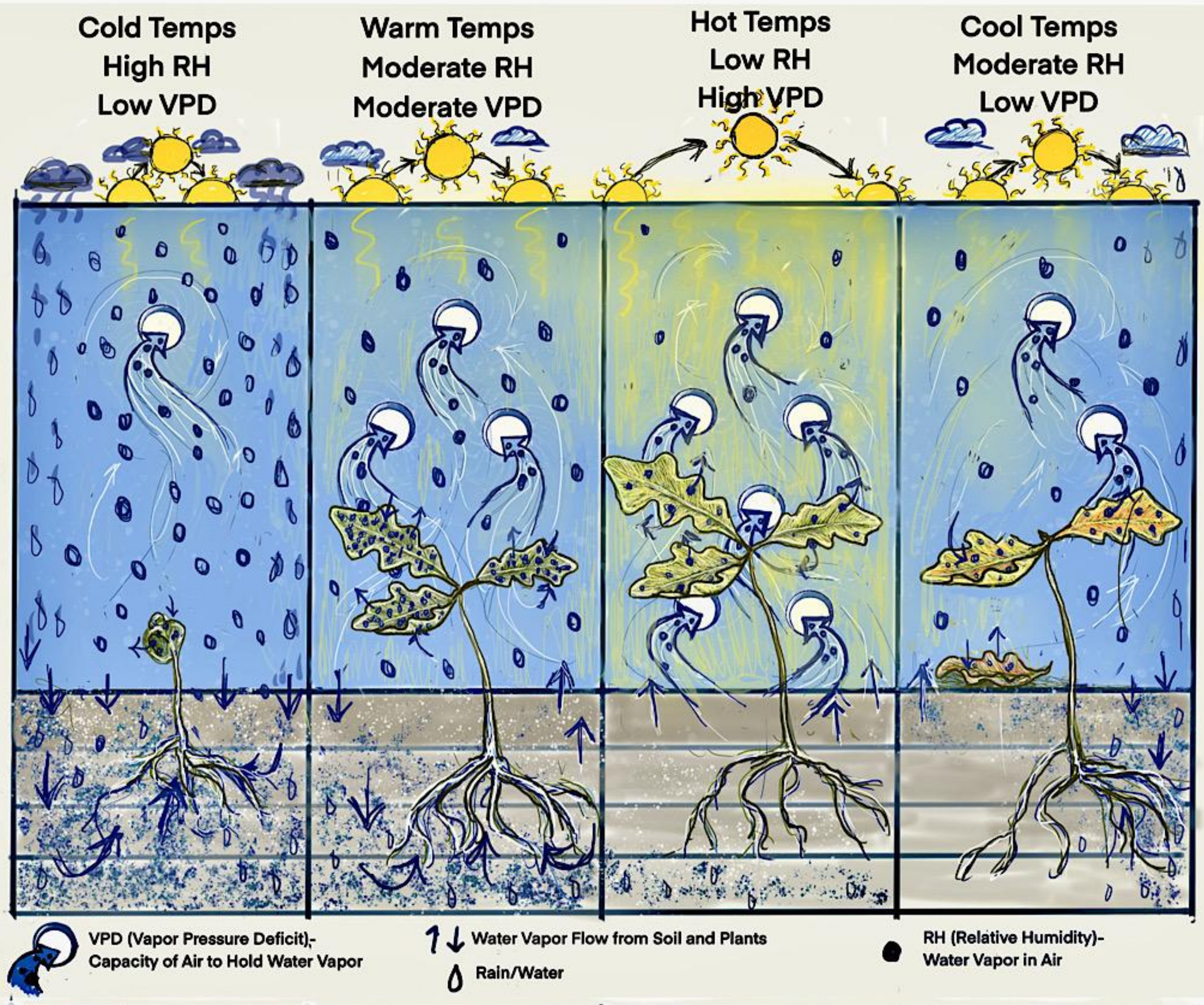


- Explain to students that they'll need to pull out their fire story zine and open to the next blank page. They will be sketching the outline of live and dead leaf (shape and primary veins only) saved from earlier, leaving some room on the page to add a few notes including the temperature and humidity (provided by teacher or looked up by student on weather site).
- Students can use a light color if desired, but the key is to add keywords and or phrases from their comparison table into the shape of their live and dead leaf that helps explain sensory and moisture differences between the live and dead leaves. Students should make larger words/text for the strongest observations. The text can be written in any pattern on and around the leaf shape and can be in color or just black and white.
- Students add the fuel size and lag time for the dead leaf and note about the lag time to reach equilibrium with the air moisture.
- Students add notes near the live leaf about the VPD feeling of the leaf based on the current temperature and relative humidity. Discuss and refer to the VPD illustration for seasonal and temperature and moisture scenarios (warm and wet= moderate VPD (temp based, but less stressed plant (water availability)

- Students add any notes or questions about the flammability of the live and dead leaves from the demonstration or in general.

See large illustration on the following page.

Live Fuel Moisture, Relative Humidity & Vapor Pressure Deficit



90-100% relative humidity good for plant germination with increasing sunlight and warming temperatures.

60-80% relative humidity good for tropical plants and warm temperatures.

Dew point and 85% + relative humidity can cause fungal growth on plants with warm temperatures.

50-60% relative humidity ideal for the vegetative growth stage of most plants with enough sunlight and warm temperatures.

40-50% relative humidity ideal for the flowering and fruiting stage of most plants with good sunlight and warm temperatures.

20-30% relative humidity okay for cacti and succulents but many plants start to dry out. 15-30% a typical red flag fire condition. High temperatures cause plants to close pores (stomata) to avoid water loss reducing photosynthesis and cooling by the transpiration process. High temperatures also increase the vapor pressure deficit even with good relative humidity stressing plants.

Deciduous trees drop their leaves as sunlight hours decrease and temperatures cool. Less water is needed and plants can wait for soils to replenish with water. Warmer temperatures can reduce soil and ground water replenishment because more water vapor is held in the air. Less soil and ground water can stress and kills trees especially evergreens.

EXAMPLE FIRE COMBUSTION OBSERVATIONS THAT CAN BE REFERENCED