BES 316 Spring 2010

**MICROENVIRONMENTAL ANALYSIS**

Goals for Today

1. To learn about approaches to field microclimate analysis
2. To understand equipment applications & limitations
3. To practice collecting microclimate data

**SCHEDULE for APRIL 29, 2010**

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| **Time Period** | **Activity** |
| 8:45 – 9:15 | Drive to St Edward State Park |
| 9:30 – 12:30 | Microclimate measurements |
| 12:30 – 1:00 | Drive back to UWB |

**MICROENVIRONMENTAL ANALYSIS: GENERAL CONCEPTS**

The environment that organisms experience (plants in particular) includes aerial and ground-based components. Often we find it important to measure and understand the environment that certain organisms experience in order to understand ecological patterns. In this lab exercise we will focus on the aerial portion of an organism’s environment – its local “climate”. In the following weeks we will conduct analysis of the other portion of a plant’s environment – soils.

It is important to consider the scale of the aerial environment that an organism actually experiences. Most of us are familiar with the general annual climate of the Puget Sound Lowlands. At these low elevations we expect moderate temperatures, dry summers, and wet winters with little snow (except this past winter!). Inherent in these expectations is a spatial scale that we find useful for describing climate, i.e., the Puget Sound region. While these general climatic patterns may seem homogeneous at a regional scale, climate is often much more variable when considered at more local scales. Climate is often described at the macro-, meso-, and micro- scales (defined below). These divisions do not have quantitative boundaries, but are useful descriptive tools to identify the general spatial scale of interest.

**Macroclimate:** The aerial environment at the scale of a large landscape region.

 *Examples: The Pacific Northwest*

**Mesoclimate:**  The aerial environment of a portion of a landscape region that may be modified by regional or local topography.

 *Examples: Eastern Washington versus western Washington as influenced by the Cascade Mountains*

**Microclimate:**  The local aerial environment, from a certain slope to the immediate vicinity of an organism; close enough to be influenced by the organism itself.

*Examples: The environment immediately adjacent to a forest floor plant; a north or south facing slope coming off of a ridgeline*

Since plants are relatively immobile, fine scale environmental variation is important in determining the success of individuals. Once a seed lands in a site, it must endure whatever conditions prevail there if it is to germinate, grow and reproduce. Disturbances within an established plant community often create substantial microclimatic variation and consequently result in small-scale changes in plant density and species composition. For instance, openings in a forest canopy (gaps) may contain greater densities of tree seedlings and different shrub species than in the adjacent undisturbed forest understory. Similar strong gradients in microclimate are found at a forest edge. For example, in old growth temperate rainforests of the Pacific Northwest there is a dramatic daytime decrease in humidity and increase in temperature as you move from the forest into adjacent clearcut areas (*see figure below*). There are also dramatic differences in the degree of temperature fluctuation in these two locations. Such edge effects characterize an ***ecotone***, a transition zone of vegetation and microclimate between two vegetation types (the forest and the clearing in this case).

Edge effects on microclimate can extend for hundreds of meters into remnant forest stands, and are an important consideration in habitat management and designing forest reserves. Chen at al. (1995) found changes in humidity and wind speed in an old-growth Northwest forest more than 240 meters from the edge of a clearcut! If the microclimate of a forest stand is influenced by an adjacent clearing for nearly a quarter of a kilometer into the forest, then the size of the forest stand that possesses stable interior microclimatic characteristics is much smaller than the whole stand.

Often, the spatial scale at which microclimatic variation is important is surprisingly small. For example, in desert shrubs, the temperature of leaves 8 cm above the soil surface can be as much as 10 °C cooler than leaves near the ground. In cold environments, the warm microclimate near the soil surface is crucial for plant success. Leaf temperatures of alpine cushion plants can exceed nearby air temperatures by more than 20 °C at midday. Important microclimatic variation can also occur through time. The microenvironmental temperature for a tree seedling growing near the ground surface in a clearcut in the lowland Puget Sound region can vary more than 40 °C over the course of a day. All of these differences in microclimate are significant enough to have important consequences for physiological processes (e.g., photosynthesis, water loss), individual growth and development, plant communities and ecosystem processes.



From Spittlehouse & Stathers (1990)

Some common climate parameters that are monitored in ecological studies and relatively simple instruments to measure them are listed below.

**PARAMETER** **INSTRUMENTS**

 Relative Humidity Psychrometers

 Temperature Thermocouples

 Solar Radiation Quantum sensors; Pyranometers

 Wind Speed Cup & Hot Wire Anemometers

There is a section at the end of this handout that provides the theory and methods for using different varieties of such instrumentation. Not all will apply to the instruments we will use, but it is there for your general background information.

As Chen et al. (1995) did, we will investigate microclimate parameters along a gradient from a clearing into the interior of an adjacent forest stand. We will be able to examine the edge effect on forest interior microclimates as Chen et al. (1995) did and see if our results are similar. We will examine vertical profiles of air temperature, leaf temperature, relative humidity, radiation, and wind speed in a clearing, at the forest edge, and 20, 50 and 100 meters into the forest stand.

 **STUDY DESIGN**

**Basic Questions**

1. How do microclimatic parameters vary as we move from a clearing into a forest stand?

2. Are these changes reflected in changes in leaf temperatures along that gradient?

3. How does air temperature and wind speed vary with height in a forest as compared to an open field?

**Experimental Design**

You will collect data as a group of 4 students. Establish a 100-m transect line into a forest stand with two 50-m measuring tapes. You should avoid major topographic features. Take measurements of all variables (below) at six locations:

1. In the clearing
2. At the forest edge
3. 20 meters into the forest
4. 50 meters into the forest
5. 100 meters into the forest
6. 150 meters (if time)

At each measurement site be sure to record relevant characteristics of the macroenvironment (e.g., cloud cover, precipitation, etc.) that might influence your microclimatic measurements. Also note the vegetation density, structure, and major plant species (or at least growth forms if you don’t know the species) in the different layers (ground cover, shrub layer, and overstory) of each of your sites. At each measurement site make measurements according to the instructions on the following page and use the data sheets provided in this handout.

**You should divide up the responsibilities among your group in order to accomplish the data collection most efficiently.**

**Equipment your group should take out to the field**

**Measuring Devices:**

1. 2 metersticks & 2 50-m tapes

**Temperature:**

1. 2 Omega HH-21 thermocouple meter
2. 2 Coarse-wire thermocouples with plug end
3. 1 single junction fine-wire thermocouple with plug end
4. 1 Soil temperature probe

**Humidity:**

1. 1 RH probe

**Solar Radiation:**

1. 1 LiCor Quantum Sensor
2. 1 LiCor 185 Radiation Sensor Readout unit

**Wind Speed:**

1. 1 Extech hot wire anemometer

**COLLECTING DATA**

You should measure air, ground surface, and soil temperature; relative humidity; wind speed; and solar radiation (photosynthetic photon flux density; PPFD) at each measurement site. Some parameters (air temperature, RH, PPFD, wind) will be measured at two heights above the ground, reflecting the microclimate experienced by ground cover plants (10 cm) and shrubs (1 meter). **Each parameter should be measured FOUR times (replicates) at each location specified to account for variability**.

**1. Air Temperature**

Using a fine-wire thermocouple and the Omega HH-21 thermocouple meter measure air temperature at 10 cm and 1 m above the ground surface.

**2. Leaf Temperature**

Using a fine-wire thermocouple and the Omega HH-21 thermocouple meter measure the temperature of four selected leaves of a common ground layer species at about 10 cm height and four leaves of a common shrub at about 1 m height.

**3. Surface Temperature**

Using copper-constantan thermocouples and the Omega HH-21 thermocouple meter measure the temperature of the ground surface (whatever material is exposed is considered the “surface”).

**4. Soil Temperature**

Using the steel soil temperature probe to measure the soil temperature at a depth of 10 cm.

**5. Relative Humidity**

Measure %RH at 10 cm and 1 m above the ground.

**6. Wind Speed**

Measure wind speed at 10 cm and 1 m above the ground with the hot wire anemometer.

**7. Solar Radiation**

Measure PPFD at 10 cm and 1 m above the ground, with sensor level to the ground.

**Are my PPFD values reasonable?**

Measurements should range from 0-2000 µmol/m2/s for PPFD (quantum sensor). Typical unobstructed sunny values will be around 1500-2000 for PPFD. Under the shade of a dense tree canopy these values can be down to as little as 5 - 10% of full sun values.

**To get your four replicate values, measure each parameter in four cardinal directions (north, south, east, west) around an upright meterstick.**

**5**

**DATA SHEETS**

Data forms are provided in this handout if you wish to use them (optional). There are not enough in one handout for any group’s needs (you’ll need to pool the forms from each of your handouts to get sufficient forms).

**PRODUCTS**

Written Report

You should submit an individual written report based upon the data from your group - due at the start of class on May 11th. You may summarize the individual data measurements as a group, but any calculations, analysis, and illustrations should be done strictly on an individual basis.

This report should include:

* A brief introduction, outlining the context and purpose of the study (citing literature – use the papaers we have read for class and lecture material). This should be no more than a paragraph or two (double-spaced please).
* A brief written summary of the results and your interpretation (this should be brief and direct, like one would find in a combined “Results and Discussion” section of a scientific paper). Please make this double spaced. There are no page restrictions, but I would not expect much more than 4 - 6 pages of text (not including illustrations). Cite references where appropriate (though I do not expect a literature search – use the class readings and other easily available materials, such as background materials from your previous course in basic ecology). **I will expect you to use the required readings (Chen et al. and Spittlehouse & Stathers) extensively**. Compare your results to those in the published papers and consider the bases for similarities and differences in trends. Use simple statistics (t-tests) where appropriate to allow you to distinguish between mean values (you should have at least 4 replicates of many of your measurements). You can compare mean values of parameters along your transect. The main analysis should focus on questions about the effects of distance into different forest patches on microclimates.
* Literature cited list

The emphasis in grading will be on your analysis, but presentation will also be a significant factor. You should treat all written products for this class as you would a professional paper with a target audience of well educated peers not taking this same class. It should be well written, with close attention paid to clarity of writing and brevity (but not at the expense of completeness).

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**DATE:**

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**VEGETATION:**

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| **Air Temperature 10 cm** | **Air Temperature** **1 m** | **Surface Temperature** | **Soil Temperature****-10 cm** | **Wind Speed****10 cm** | **Wind Speed****1 m** | **RH** **10 cm** | **RH** **1 m** | **PPFD** **10 cm** | **PPFD** **1 m** |
| (°C) | (°C) | (°C) | (°C) | (m/s) | (m/s) | (%) | (%) | (µmol/m2/s) | (µmol/m2/s) |
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| **Leaf Temperature 10 cm** | **Leaf species** | **Leaf Temperature 10 cm** | **Leaf species** |  | **Leaf Temperature 1 m** | **Leaf species** | **Leaf Temperature 1 m** | **Leaf species** |
| (°C) |  | (°C) |  |  | (°C) |  | (°C) |  |
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| **Air Temperature 10 cm** | **Air Temperature** **1 m** | **Surface Temperature** | **Soil Temperature****-10 cm** | **Wind Speed****10 cm** | **Wind Speed****1 m** | **RH** **10 cm** | **RH** **1 m** | **PPFD** **10 cm** | **PPFD** **1 m** |
| (°C) | (°C) | (°C) | (°C) | (m/s) | (m/s) | (%) | (%) | (µmol/m2/s) | (µmol/m2/s) |
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| **Leaf Temperature 10 cm** | **Leaf species** | **Leaf Temperature 10 cm** | **Leaf species** |  | **Leaf Temperature 1 m** | **Leaf species** | **Leaf Temperature 1 m** | **Leaf species** |
| (°C) |  | (°C) |  |  | (°C) |  | (°C) |  |
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**WEATHER:**

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**VEGETATION:**

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| **Air Temperature 10 cm** | **Air Temperature** **1 m** | **Surface Temperature** | **Soil Temperature****-10 cm** | **Wind Speed****10 cm** | **Wind Speed****1 m** | **RH** **10 cm** | **RH** **1 m** | **PPFD** **10 cm** | **PPFD** **1 m** |
| (°C) | (°C) | (°C) | (°C) | (m/s) | (m/s) | (%) | (%) | (µmol/m2/s) | (µmol/m2/s) |
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| **Leaf Temperature 10 cm** | **Leaf species** | **Leaf Temperature 10 cm** | **Leaf species** |  | **Leaf Temperature 1 m** | **Leaf species** | **Leaf Temperature 1 m** | **Leaf species** |
| (°C) |  | (°C) |  |  | (°C) |  | (°C) |  |
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**Instrumentation: Principles & Operating Procedures**

This section provides an introduction to some of the instruments commonly used in microenvironment analysis. You are expected to read this section. A detailed coverage of these instruments and more sophisticated alternatives is outside of the scope of this course but some of the additional readings listed provide a good introduction (especially Jones 1985 and Pearcy et al. 1987) if you are interested (not required).

**I. TEMPERATURE**

**1. Thermocouples**

***Principles***

A thermocouple is simply two wires of different metals that are joined into a loop by connecting them at both ends. It operates on a principle known as the "Seebeck Effect": when two unlike metals are joined into a loop and the two junctions are held at different temperatures, an electrical current will flow through the loop. The amount of current is directly proportional to the difference in temperature of the two junctions.

Copper wire

Reference junction

*Measuring junction*

Constantan wire

The Seebeck effect illustrated for a copper-constantan thermocouple. The arrows indicate the direction of current flow if the reference junction temperature is higher than that of the measuring junction. The voltage generated by this current flow is measured by inserting a voltmeter into either leg of the loop.

Thus, if one junction is held at a known (reference) temperature and the current measured, the temperature of the other junction (measuring junction) can be deduced. The relationship between junction temperature difference and current is well known for a number of pairs of metals, but the most popular for ecological applications is copper and constantan. Constantan is a copper-nickel alloy. The associated thermocouple meter acts as electronic reference junction, which eliminates the need for holding one junction at a known constant temperature. The measuring junctions can be made inexpensively of very fine wire suitable for measuring temperatures of leaves as well as soil and air. They are typically arrayed in the environment and attached to an electronic datalogger that records the thermocouple temperatures continuously through the desired time period. A useful feature employed in studies of plant temperature and environment is that a number of measuring junctions connected in parallel will yield the mean temperature of those junctions. Investigators interested in average leaf temperatures over an entire plant can easily obtain this by attaching several leaves within a plant to junctions wired in parallel.

**2. Hygrothermograph**

These recording devices that measure temperature and relative humidity are rarely used in these electronic / computer days. You should be aware of their existence though as they have some significant advantages over modern electronic equipment under certain circumstances. They are relatively cheap and less prone to vandalism (or less expensive to replace if it occurs). They are easy and fun for school children to use and produce a graphical display that is easy to interpret. They also require no power source.

Temperature is measured from the principle of metal expansion and contraction with temperature changes. There is a curved bimettalic strip inside the hygrothermograph. The two metal have different thermal expansion sensitivities. As the temperature changes the metals expand / contract at different rates, changing the curvature of the metal strip. This is attached to a recording pen by an armature. The recording pen records temperature on a revolving drum (powered by a wind-up clock – wow, now that’s a piece of history!). Humditity measurements are described in the section below.

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**II. RELATIVE HUMIDITY**

**1. Psychrometers**

***Principles***

The psychrometric measurement of humidity is based on the principle that the rate of water evaporation into air is proportional to the water content of the air. The rate of water evaporation into air is measured by the temperature drop of a thermometer bulb surrounded by saturated wick material. The drier the air, the faster the rate of evaporation from the saturated wick material, and the lower the temperature of that "wet bulb" (due to evaporative cooling) relative to the paired dry bulb. This temperature difference is called the “wet bulb depression”. In order to maintain a constant rate of evaporation from the wet bulb and achieve a steady reading, it is necessary to provide a moving air stream past both thermometer bulbs. The sling psychrometer uses muscle power, while the aspirated psychrometer utilizes a mechanical fan.

***Operation of Sling Psychrometer***

Prior to making a measurement check the wick of the wet bulb to be sure it is saturated. If necessary, add a small amount of distilled water from a squeeze bottle. With the sling psychrometer, keep a good grasp on the instrument base, clear the surrounding area of friends and family, and vigorously spin the thermometer bulbs at least a dozen times. The aspirated psychrometer utilizes a wind-up fan to aspirate the thermometer bulbs. Tables are available to determine the % relative humidity from the wet and dry bulb temperatures.

**2. Hygrothermograph**

Relative humidity is measured in a hygrothermograph with blond human hair. Yes, that’s right – blond human hair. It turns out that blond hair expands and contracts in a fairly linear fashion with changes in relative humidity of the air. Blond hair is more linear than black or brown. Please don’t ask me why. The hairs are stretched between two clamps and their expansion / contraction moves a recording pen that records RH on the same drum as that for temperature described above.

**3. Solid State Sensors**

There are a variety of solid-state electronic humidity sensors available. These sensors either change characteristics of electrical capacitance or resistance with humidity changes. This means that they require a source of electrical current to be measured (e.g., batteries or line power). They are generally quick, easy to use and can be hooked up to an electronic datalogger for continuous recording. Although these tend to be the senors of choice in modern research there are two cautions worth noting. First, these senors tend to go out of calibration reasonably often. Ten years ago one had to calibrate these sensors weekly for continuous use (or even daily if they were being used to measure plant transpiration in enclosed chambers) – now they are more stable but still require biweekly or monthly calibration. It is a good idea to calibrate at least weekly until you are convinced they are stable enough to leave for longer time periods. Secondly, their electrical response is often non-linear at either very high or very low humidity. This is a real problem if one is using 0% relative humidity as one of the calibration points (a common point because it is relatively easy to generate air with 0% RH).

**III. WIND SPEED**

**1. Cup Anemometers**

In class you will see a variety of classical cup anemometers for measuring wind speeds. These vary from small handheld units to larger 3-cup ones that are visible on many weather stations. Cup anemometers are convenient and simply operate on the principle of air forcing the rotation of a spindle on which the cups are suspended. This spindle must rotate freely, with a minimum of friction and inertia. This is where the primary limitations of cup anemometers come in. These instruments vary greatly as to their frictional resistance and interial characteristics. They also tend to be very directionally dependent (readings vary with drection of wind relative to the horizontal plane of the cups), though some of the newer units are better in this regard.

**2. Hot Wire Anemometers**

***Principles***

The typical measurement of wind velocities are made with the familiar 3-cup anemometers you see twirling about most weather stations. These instruments are not very sensitive and are often too large to effectively characterize the wind environment in the microclimate of a plant. Hot wire anemometers were developed on the principle of convective heat loss. The rate of heat loss from an object in an air stream is a function of the windspeed and the difference in temperature between the object and the air. In these instruments, a wire is heated electrically to a constant temperature well above air temperature. This heated wire is exposed to the environment and the temperature of the wire is maintained constant electronically. The amount of added current required to maintain the high temperature of that wire is measured and the wind speed is calculated from that value and the difference in air and wire temperature. Air temperature is measured very close to the hot wire by an integrated thermocouple.

***Operation***

Zero the instrument while the hot wire is still covered to block wind flow. Actual readings in most microenvironments will fluctuate greatly. This is simply the reality of complex turbulent air flows that occur close to vegetation or the ground surface. To get a good measurement, have one person hold the probe as steady as possible, a second person read the panel meter out loud and a third person record numbers. Be careful that your presence does not interfere with the wind you are measuring! While holding the probe in a location take 10 - 20 sequential readings, one immediately after the other, as fast as you can coordinate calling them out and writing them down. Average those readings for one actual value. Be careful that the opening of the probe is oriented horizontally (parallel to the ground) and into the wind.

**IV. SOLAR (SHORTWAVE) RADIATION**

**1. Radiometers**

***Principles***

LiCor radiation sensors (a very common type) are silicon photocells with special optical filters. They operate on the principle that shortwave radiation striking a silicon photocell will cause electrical current to flow. The flow of current is in direct proportion to the amount of radiation striking the photocell. The two most common sensors, the quantum sensor and the pyranometer, are actually the exact same silicon cell element fitted with different optical filters. The quantum sensor is filtered to give an equal response to all photons from 400-760 nm in wavelength regardless of the fact that the energy content of photons vary across that range. This was done to reflect the amount of radiation available to drive photosynthesis. In a simplistic sense, photosynthesis responds to the amount of photons incident between 400 and 760 nm, not the energy content of the radiation. Thus, to measure the amount of radiation available for photosynthesis, the silicon cell was filtered to deliver a response proportional to the amount of photons in that waveband, not their energy. This is termed "photosynthetic photon flux density" (PPFD) or "photosynthetically active radiation" (PAR) and is given in units of µmoles photons/m2 of surface area/s. You may also see reference to µEinsteins/m2/s, which is equivalent because an Einstein is a mole of photons.

Measurements of the temperature relations of plants require a measure of the energy content of the incident radiation, rather than the PPFD. The pyranometer is filtered to measure the total energy content (Watts/m2) of incident shortwave radiation (350 - 2000 nm). The relationship between the energy content and photon content of radiation depends upon the spectral distribution of the light source in question. Thus, appropriate conversions must take in account what light source is being measured (see table below). The same goes for conversions of lux (commonly seen in older literature) to PPFD. We will only use a quantum sensor to measure PPFD in this lab exercise.

Approximate conversion factors for various light sources for photosynthetically active (visible) radiation (400-700 nm).

Light source

Daylight Metal Sodium Mercury White Incand.

Halide (HP) fluor.

To convert Multiply by

W m-2 (PAR) to 4.6 4.6 5.0 4.7 4.6 5.0

µmol m-2 s-1 (PAR)

klux to 18 14 14 14 12 20

µmol m-2 s-1 (PAR)

klux to W m-2 (PAR) 4.0 3.1 2.8 3.0 2.7 4.0

*data courtesy of Li-Cor Co., Lincoln, Nebraska*

***Operation***

Full sun values in the summer for the quantum sensor will be around 1800-2000 µmol/m2/s and for the pyranometer about 1000 W/m2. These values will be approximately 10% less at this time of year and may be reduced greatly by cloud cover and shade. Both sensors should be held carefully level (horizontal – use the leveling bubble!) and be sure not to shade the sensor with your hand or arm!

***Literature Resources***

**These are advanced readings referenced here for your possible future benefit (but the list includes the two required readings for completeness). The other readings are NOT required or recommended at this time.**

Barbour, MG, JH Burk, and WD Pitts (1987) Terrestrial Plant Ecology, Chapter 14 (especially pages 329-346).

Campbell, GS (1977) An Introduction to Environmental Biophysics. Springer-Verlag, Berlin.

Chen, J, JF Franklin, and TA Spies (1993) Contrasting microclimates among clearcut, edge, and interior of old-growth Douglas-fir forest. Agric. Forest Meteorol. 63:219-237.

Chen, J, JF Franklin, and TA Spies (1995) Growing-season microclimatic gradients from clearcut edges into old-growth Douglas-fir forests. Ecological Applications 5: 74-86.

Gates, DM (1980) Biophysical Ecology. Springer-Verlag, Berlin. 611 p.

Grace, J, ED Ford, and PG Jarvis, Eds (1981) Plants and their atmospheric environment. Blackwell Sci Pub, London. 419 p.

Kira, T and K Yoda (1989) Vertical stratification in microclimate. pp. 55-71 in H Leith and MJA Werger (eds.) Tropical Rainforest Ecosystems. Elsevier Publ., Amsterdam.

Jones, HG (1983) Plants and Microclimate. Cambridge Univ. Press, Cambridge. 323 p.

Jones, MB (1985) Plant microclimate. pp.26-40 in J Coombs, DO Hall, SP Long, and JMO Scurlock (1985) Techniques in Bioproductivity and Photosynthesis. 2nd Ed. Pergamon Press, NY.

Lange, OL, PS Nobel, CB Osmond, and H Ziegler, Eds. (1981) Plant Physiological Ecology I. Responses to the Physical Environment. Encyc. Plant Physiol. New Series Vol 12A. Springer-Verlag, Berlin. 625 p.

Pearcy, RW, J Ehleringer, HA Mooney, and PW Rundel, Eds. (1987) Plant Physiological Ecology: field methods and instrumentation. Chapman and Hall Publ., NY. 457 p.

Spittlehouse, DL and RJ Stathers (1990) Seedling Microclimate. British Columbia Ministry of Forests Management Report No. 65. 28 p.