Guidelines for Successful Soil Temperature Monitoring

Soil temperature monitoring is the recording of the temperature of soil at specific levels below the surface. Although natural radioactivity and conduction from the earth's core contribute small quantities of heat, the main drivers affecting soil temperature in the upper meters come from solar radiation and heat exchanges at the surface (AES, 1978).

This heat process is dependent upon seasons, cloud cover, plant cover and physical soil properties such as soil type, compaction and moisture content (AES, 1978). As atmospheric processes are reflected in soil temperatures, tracking soil temperature can be a valuable variable in monitoring climate change.

This white paper will discuss how soil temperatures differ according to forest type as well as its influence on insects, wildlife and vegetation.

Equipment

- Data Logger
- Meter stick (for snow depth measurements in winter)
- Fishing line
- Shovel or Trowel
- Ruler
- Wooden stake
- Data sheets and pens
- Site map
- Camera

Research Question

Soil temperature monitoring involves placing temperature data loggers in the soil to record the temperature and the daily, monthly, seasonal and annual variation. The sampling design will vary depending on the research question or the objectives of the research program.

Soil temperature can be used to give background data to other monitoring programs such as plant phenology, soil decay rate, species diversity, invertebrate studies, worm diversity etc. In associating soil temperature information with other protocols, soil temperature baseline information should be collected in the area that would most affect the main item under study.

There are five steps in evaluating and designing research.

1. Defining goals and objectives:

What does your organization want to study and why. In terms of Soil Temperature, there are many different possibilities. We offer some suggestions and examples but it is by no means an exhaustive list of possibilities in terms of using Soil Temperature monitoring as part of a monitoring program.

- **Simple goal:** Your study involves a yes or no answer: Does the soil freeze? Is the soil temperature changing? Does soil temperature relate to plant phenology/soil decay rate/species diversity?
- **Comparative goal:** Your study involves the comparison of two or more parameters: Does soil temperature in site A differ from soil temperature in site B (i.e. forests versus fields). Is soil temperature more variable in soil type A than in soil type B. What is the soil temperature relationship between topsoil and deeper soil?
- **Complex goal:** Your study has various levels of investigation, asking a more complicated question: How is the soil temperature changing? What is the soil temperature regime in Site A? What is the soil temperature regime in multiple sites?

For more involved questions such as – is the soil temperature changing and if so, why is it changing? – then soil temperature protocols will have to be paired with other monitoring protocols and will require more in-depth study.

2. Sampling design:

Different sampling designs relate to different research questions.

- **Single Level Study:** Recording soil temperature at a single depth in the soil.
- **Paired Level Study:** Recording soil temperature at a single depth in the soil at two or more sites OR Recording soil temperature at two different depths.
- **Multiple Level Study:** Recording soil temperature at multiple depths in the soil can be done at two or more sites.

In general, simple goal research can use single level studies while paired studies can be used for comparative goal research. Complex goal research relates to multiple level study but can also incorporate paired levels study and additional associated protocols.

3. Methods for analysis:
This depends on the specific research questions being asked. Soil temperature can be graphed to find seasonal changes. Daily averages can be plotted against time on a line graph to show seasonal variations. If comparing sites, a graph from site A can be compared to site B graph to determine any differences in temperature changes or delays in soil warming/cooling. Soil temperature data can also be paired with air temperature for correlation. If collecting additional protocol data, graphs for soil temperature can be related to phenology events, snow depth and other criteria.

4. Communicate the results:
Annual/bi-annual reports are a good way to record monitoring status and trends, and can be useful in determining whether current research goals and objectives are being met through the monitoring program.

5. Integrate monitoring into decision-making:

Once trends are detected and potential problems identified, decisions can be made on how to address the ecological issues. Initial monitoring can explore the status of a site, then research can be directed towards the question of "why". Why is this variable changing/degrading/disappearing. Environmental management tools can be incorporated into land use planning, area management and decision-making to mitigate problems and address environmental issues as they arise.

Deployment Considerations Siting
A site for monitoring soil temperature can be established in a forested area, near a river or lake or near a wetland. This protocol can also be done in association with forest biodiversity monitoring plots.

Sites need to be easily accessible and free of hazards. In all cases once a site it chosen, fill in a site description datasheet for the location. Site characteristics need to be recorded and the soil temperature station should be plotted on a site map. Photographs of the site may also be useful in describing the sample area.

Data loggers should be buried in an area of the site that:
- Has soil that has been left undisturbed for four or more years.
- Is representative of the site.
- Is a good distance from any source of heat such as heated buildings or manmade objects.
- Is close to or under trees as this is usually an indication of good soil.
- Is in an area which is easy to find and easy to access for sampling purposes.
- Is on a flat and level surface, preferably covered with vegetation (AES, 1978).

Data loggers should NOT be buried in an area of the site that:
- Is in a forest gap. There is usually a reason why these are gaps in the forest such as poor soil quality, which may not be representative of the site under study.
- Is inside a research plot, as placement of data loggers requires the disturbance of soil.
- Is next to rocks as they can affect temperature, unless the area is entirely rocky, in which case rocky soil is representative of the site.
- Is in depressions or on slopes where unusual moisture conditions could exist (AES, 1978).

Habitat Type and Depth of Data logger
In order to study biodiversity and impacts of climate change, the most useful information on soil temperature comes from the layer used by biological species.

As a general recommendation, in studying plant biodiversity, soil temperature should be recorded at the root layer as this is the most important layer for prediction purposes. At a single depth, 10cm into the mineral soil (after the organic or humus layer has been cleared) is the depth most recommended (MacIver & Auld, pers comm). For multiple layer studies, loggers can be set up in the mineral soil at 10cm, 20cm and 50cm, as a 50cm depth will be relatively stable in terms of temperature variation.

Generally, the organic layer or 5cm into the mineral soil is too variable and the data too spiky to follow changes over time. However, if the subject under study is a specific invertebrate species, the habitat of insects, mold or disease, recording soil temperature in the organic layer would be recommended.

Open areas are considerably more variable in terms of soil temperature than closed forests and the soils in open areas will generally freeze. Therefore in forested sites, data loggers should be placed in the forested areas (unless a paired study is being conducted) and should be placed 10cm into the mineral soil, not including the organic layer. Ecozone(s) and site types should be taken into consideration when determining logger depth placement. The following are areas that will require different depths for data loggers:

- **Coastal Forests:** The organic layer in coastal forests can be very deep and does not normally freeze due to mild climate. This area has different thermal profiles than boreal forests. Again, it will be important to place data loggers in the plant root zone, which may be in the humus layer. It is recommended that an initial investigation into the ground vegetation root layer be done in order to determine the depth of burial. In general, the root zone is located10-20cm into the organic layer.

- **Wetlands:** Wetland areas are also made up of deep layers of organic soils. Bogs and black spruce swamps tend to have shallow rooted species and data loggers can generally be buried 10cm into the ground, including the organic layer. Depending on the wetland habitat type, initial investigation of the root zone should be done and the data loggers placed accordingly (generally 10-20cm below the surface in the organic layer)

- **Grasslands:** Soil temperatures in prairie areas will be more variable due to wind and open field conditions. Soils in open areas tend to freeze over winter in northern areas. Data loggers can still be placed in the mineral soil at a depth of 10cm, but the logger will need to be able to record temperatures below –5°C.

Soil Temperature Monitoring Methods

Timing

1. Placement of the logger should be done in the warmer season, preferably summer as the temperature changes occurring in spring and autumn are important for soil study and phenology.

2. Collection of the loggers and replacement will depend on the monitoring program. Is the data needed seasonally or annually? If data is needed seasonally, four data loggers can be placed at the site and one collected per season (instead of removal and replacement each time), to ensure a minimum amount of soil disturbance and a continual sample.

Installation and Marking

Installation should be done with the least amount of disturbance to soils as possible:

1. Attach a 3m piece of nylon fishing line to the case of the temperature logger.

2. Check that the light on the temperature logger is blinking, to confirm that the logger is operational (unless stealth mode is in effect – in which case you will not be able to ensure that the logger is operational).

3. Using a shovel or trowel, dig a small trench – see SITING section for site placement instructions.

4. Measure down 10cm from mineral soil layer (For multiple layer studies, follow the same procedures for 20cm depths and 50 cm depths. Do not place data loggers directly under each other, move slightly right or left of upper loggers).

5. Secure the fishing line on data logger(s) to a wooden stake

6. Place a wooden stake into the trench and push the attached data logger thermometer(s) sideways into the trench so as not to disturb the above soil

7. Backfill the trench with the stake sticking out and map the area for future reference.

8. Fill out site information on the soil temperature data sheet.

Snow Depth Measurements

1. Snow depth measurements should be taken along with soil temperature.

2. The frequency of snow depth measurements should be decided upon depending on the accessibility of the site and the availability of a volunteer or field researcher to record snow depth. It is recommended that snow depth be taken at least twicemonthly and more whenever possible.

3. To record snow depth, go to monitoring site and locate burial site using the map and the stake.

4. Place a meter stick into the snow down to the soil. If snow levels are higher than one meter, mark meter height and measure excess.

5. Record snow depth in cm on the soil temperature data sheet.

Using daily averages, conduct data analysis as per research question, through the use of graphing. If multiple depths are used calculate the sum and mean of the temperature at each depth and graph.

Pair air temperature of the area with soil temperature and/or with additional protocol data to identify relationships. For local information, compare yearly profiles with weather events and snowfall.

Use the snow depth measurements and relate this to soil temperature to see if depth has a buffering effect. If associating soil temperature with other protocols (such as

plant phenology), compare associated protocol data with and soil temperature changes.

References

Atmospheric Environment Service (AES). 1978. Soil Temperature: Manual of standard procedures for obtaining soil temperature data. Atmospheric Environment Service. Central Services Directorate, Canada.

About Onset

Onset Computer Corporation has been producing small, inexpensive, battery-powered data loggers and embedded controllers since 1981, and has sold over one million loggers that are used around the world by over 50,000 customers. The company manufactures a broad range of data logger and weather station products that are used to measure temperature, humidity, light intensity, voltage, and a broad range of other parameters. Onset products are used widely in research, commercial, industrial, and educational applications.

Onset Computer Corporation
http://www.onsetcomp.com
1-800-564-4377 / 508-759-9500
Fax: 508-759-9100
sales@onsetcomp.com