Suitability for Aerobic Soil Organisms

Soil is the habitat for a wide variety of organisms, ranging from viruses, bacteria, fungi, nematodes and a variety of others. Bacteria and fungi provide many services in soils. For example, bacteria convert plant and animal tissues into humus. Many of the resultant compounds bind the soil into aggregates. Bacteria may fix nitrogen for plant use and fungi assist plant roots in obtaining nutrients and water. Soil microbes are generally most abundant in the surface layer since they typically are found around plant roots. Soils vary in their ability to foster plant growth and thus also in their ability to support microbial populations. These differences can be caused by natural, inherent soil and site properties or can be the result of dynamic soil properties that are influenced by management, good or bad. Two major classifications of soil organisms are aerobic and anaerobic depending on the presence or absence of oxygen.

Several site and soil properties are major attributes in the suitability, in terms of survival and growth rates, of soil for various organisms. On a broad scale, trends in temperature (heat) and precipitation (water) govern the rates of respiration since biologic processes are temperature dependent and soil organisms exist in films of water. The organic matter content of the soil is always a major factor in microbial populations since they are typically saprophytic. The pore space in the soil influences water and gas movement as well as the volume for organisms to occupy and the tortuosity of paths through which they may move. The water content of the soil is important as when too much water is present anaerobic processes begin and when too little is present the organisms may go dormant. Osmotic conditions are also important, as are the presence of toxic materials or the absence of required elements.

This interpretation is being provided for review and comment by the user community. Please forward any feedback to the Soils Hotline [soilshotline@lin.usda.gov](mailto:soilshotline@lin.usda.gov).

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Criteria Table

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Site or Soil Attribute | Level of Suitability | | | Impact |
|  | Poorly suited | Moderately suited | Well suited |  |
| pH 0-30cm | Less than 4.0  Greater than 9.0 | Between 4.0 and 6.0  Between7.0 and 9.0 | Between 6.0 and 7.0 | Micronutrient availability |
| Mean annual air temperature (C) | Less than 0  Greater than 50 | Between 0 and 15  Between 24 and 50 | Between 15 and 24 | Amount of heat required for adapted species |
| Moisture relations Maximum of A-C |  |  |  |  |
| A. Mean annual precipitation minus annual potential evapotranspiration (mm) | Less than -100 | Between -100 and 100 | Greater than 100 | Moisture available for organisms |
| B. Water table depth during the growing season (cm) | 0 or less | Between 0 and 30 or between 50 and 100 | Between 30 and 50 | Moist but not saturated conditions |
| C. Root zone AWC (cm) | Less than 3 | 3 to 30 | Greater than 30 | Retains moisture between rainfall events |
| Electrical Conductivity (dS/m) | Less than 0.3  Greater than 9.0 | Between 0.3 and 0.75 or between 1.5 and 9.0 | Between 0.75 and 1.5 | Cations for mineral needs but not saline |
| Aluminum saturation 0 to 30cm (percent) | 100 | Between 2 and 100 | Less than 2 | Aluminum toxicity |
| Organic matter content 0-30cm (percent) | Less than 0.3 | Between 0.3 and 3.0 | Greater than 3.0 | Energy source for soil organisms |
| Bulk density difference ratio maximum from 0 to 30cm | Greater than 1.0 | 0 to 1.0 | 0 or less | Metric of pore space and soil strength |
| Clay content weighted average from 0 to 30cm (percent) | Less than 30 | Between 30 and 40 | Greater than 40 | Surface area for microbes |

Criteria

1. The pH of the soil at 30cm is used as an indicator of how conducive the soil is to the growth of soil organisms. Soil solution pH impacts several processes in soil. The solubility of potentially toxic elements in soils is pH dependent and may impact the vigor and diversity of microbial populations.

Property used: WTD\_AVG PH 0-30cm OR ABOVE RESTRICTION

Suitability limits:

less suited to the growth of soil organisms pH <5.0

well suited to the growth of soil organisms pH 5.0-8.0

less suited to the growth of soil organisms pH >8.0

Null pH is assigned to the "not rated" class.

2. Mean annual air temperature – While soil temperature is the best metric for assessing the amount of heat available for the growth of soil organisms, mean annual air temperature is used as a proxy. It is understood that the mean annual soil temperature will be several degrees higher. Also, it is understood that the temperature that the organisms are dealing with may be much higher or lower than the mean.

Property used: MEAN ANNUAL AIR TEMPERATURE

Suitability limits:

Poorly suited MAAT less than 1C or greater than 50C

Moderately suited MAAT between 0 and 15 or MAAT between 24 and 50C

Well suited MAAT between 15 and 24C

Null mean annual air temperature is assigned to the "not rated" class.

3. Moisture relations – The spatial and temporal distribution of water in soil is governed mainly by three relationships. One relationship is the basic difference between the amount of precipitation and potential evapotranspiration a soil experiences. More precipitation is needed for soil organisms to thrive in warmer climates, or, conversely, less precipitation is needed in cooler climates. Another feature that can influence the water content of soil is the presence of a water table (a zone of saturation) that can either drown organisms if it is too shallow or provide subirrigation if the water is in a depth where the organisms can use it. Finally, precipitation that a soil does receive must not be allowed to rapidly move through the soil, but rather be stored.

A. Property used: PRECIPITATION MINUS POTENTIAL EVAPOTRANSPIRATION, MM/YEAR

Suitability limits:

poorly suited to the growth of soil organisms less than -100mm/yr MAP-PET

moderately suited to the growth of soil organisms -100 to 100 mm/yr MAP-PET

well suited to the growth of soil organisms greater than 100mm/yr MAP-PET

Null MAP or PET is assigned to the "not rated" class.

B. Property used: WATER TABLE DEPTH, GROWING SEASON

Suitability limits:

poorly suited to the growth of soil organisms saturated at surface or greater less than -100cm

moderately suited to the growth of soil organisms between 0 and 30cm or 50 to 100cm

well suited to the growth of soil organisms between 30 and 50cm

Null water table depth is assigned to the “poorly suited” class.

C. Property used: AWC 0-150cm OR FIRST ROOT RESTRICTIVE LAYER

Suitability limits:

poorly suited to the growth of soil organisms AWC of 0cm

moderately suited to the growth of soil organisms AWC between 0 and 30cm

well suited to the growth of soil organisms AWC greater 300cm

Null AWC is assigned to the “not rated” class.

4. Electrical conductivity – The electrical conductivity of soil is a measure of the amount of cations available in soil solution. These cations are present in the soil solution. In regions that receive less precipitation than evapotranspiration, these ions can accumulate to the point where they saturate the exchange complex and become concentrated enough to seriously impact the osmotic relations of organisms. In highly leached systems, the concentration of basic cations mat be too low to support thriving populations of soil organisms.

Property used: BULK EC 0-30cm OR ABOVE RESTRICTION

Suitability limits:

poorly suited EC less than 0.3 or greater than 10 dS/m

moderately suited EC between 0.3 and 0.75 or between 1.5 and 10 dS/m

well suited EC between 0.75 and 1.5 dS/m

Null EC is assigned to the “not rated” class.

Derivation

base table component.

# Retrieves the weighted average electrical conductivity from the surface to 150cm or to a restrictive layer. The weighted average EC is for that portion of each horizon in the depth range.

EXEC SQL select hzdept\_r, hzdepb\_r, ec\_l, ec\_r, ec\_h

from component INNER JOIN chorizon ON component.coiid=chorizon.coiidref;

SORT BY hzdept\_r

AGGREGATE column hzdept\_r none, hzdepb\_r none, ec\_l none, ec\_r none, ec\_h none.

# Determine the depth to RESTRICTIVE LAYER.

# Determine the LAYER THICKNESS IN RANGE; ABOVE A RESTRICTIVE LAYER.

DERIVE layer\_thickness from rv using "NSSC Data":"LAYER THICKNESS IN RANGE; ABOVE VSTR RESTRICT BELOW O" (0,30).

DERIVE depth from rv using "NSSC Data":"DEPTH TO FIRST STR/VSTR CEMENTED BELOW ORGANIC LAYER".

DERIVE o\_thickness from rv using "NSSC Pangaea":"THICKNESS OF SURFACE ORGANIC HORIZON".

DERIVE cec\_b from rv using "NSSC Data":"MEQ 0-30cm OR RESTRICTION".

DERIVE clay\_b from rv using "NSSC Pangaea":"WTD\_AVG CLAY CONTENT 0-30cm OR ABOVE RESTRICTION".

DERIVE sand\_b from rv using "NSSC Data":"WTD\_AVG SAND CONTENT 0-30cm OR ABOVE RESTRICTION, NO O".

ASSIGN ec\_l isnull(ec\_l) ? 0 : ec\_l.

ASSIGN ec\_r isnull(ec\_r) ? 0 : ec\_r.

ASSIGN ec\_h isnull(ec\_h) ? 0 : ec\_h.

DEFINE cec\_cond cec\_b/140.

#Some electrical conductivity is related to the CEC and clay activity.

DEFINE silt\_b 100 - (clay\_b + sand\_b).

DEFINE miner\_cond (((clay\_b/100)\*100)+((silt\_b/100)\*10)+((sand\_b/100)))/100.

ASSIGN miner\_cond isnull(miner\_cond) ? 0 : miner\_cond.

#Some electrical conductivity is related to the silts and sands.

# Find minimum of restriction depth and 200cm

DEFINE min\_depth depth < 201 and not isnull(depth) ? depth : 200.

DEFINE in\_range isnull (hzdepb\_r) ? hzdepb\_r : (hzdepb\_r - o\_thickness <= min\_depth ? 1 :

hzdepb\_r - hzdept\_r >= min\_depth ? 1 : 0).

#When the restriction is at the surface, in\_range is never 1, so the weighted average

#calculation fails due to unequal dimensions. If the restriction is at the surface,

#we make depth hzdept\_r. We do not want to always make in\_range 1, only when the restriction

#depth is 0. Default needs to be dimension 0.

assign layer\_thickness depth == 0 ? hzdept\_r : layer\_thickness.

assign in\_range layer\_thickness < 0 ? 1 : in\_range.

DEFINE default 0\*layer\_thickness.

define ec\_cond wtavg((if hzdepb\_r - o\_thickness <=0 THEN default ELSE lookup(1, in\_range, ec\_r)), layer\_thickness).

define rv round ((ec\_cond+miner\_cond+cec\_cond), 2).

#The sum of the EC from salts, minerals, and CEC is given as the bulk EC.

5. Aluminum saturation – In highly acidic soils, aluminum species can become the dominant cation in soil solution. In high concentrations, aluminum can be toxic to soil microorganisms. Aluminum can become the dominant cation on the exchange complex and can even come to saturate the CEC of some soils.

Property used: ALUMINIUM SATURATION WTD AVE TO 30CM

Suitability limits:

poorly suited Aluminum saturation above 100 percent

moderately suited Aluminum saturation between 2 and 100 percent

well suited Aluminum saturation less than 2 percent

Null EC is assigned to the “not rated” class.

6. Organic matter – Organic matter in the soil acts as an energy source for many organisms.

Property used: WTD\_AVG OM 0-30cm OR ABOVE RESTRICTION

Suitability limits:

poorly suited Organic matter content less than 0.3 percent

moderately suited Organic matter content between 0.3 and 3.0

well suited Organic matter content greater than 3.0 percent

Null organic matter is assigned to the “not rated” class.

7. Bulk density – The bulk density of a soil provides information about the macropore space and the strength of the soil. Since organisms live and gases and water flow through the macropores, they are a significant attribute of soil. However, just the number for bulk density is not very informative, since the soil texture and the density of the soil particles are also factors in identifying an optimal soil density for biologic components. A sandy soil having a bulk density of 1.4 g/cm3 might not be limited but a clayey soil of the same density will be. In order to obtain a meaningful metric, an ideal bulk density is calculated for the soil sand, silt, clay, and organic matter content, then this is compared to the observed bulk density. Just the difference is not entirely informative, because the change in density between ideal and limiting changes for each texture. In other words, a 0.15 g/cm3 increase in the density of a clayey soil may be more problematic that a similar increase in a sandy soil.

Property used: BULK DENSITY RATIO MAXIMUM 0 TO 30CM

Suitability limits:

poorly suited Density ratio greater than 1.0

moderately suited Density ratio greater between 0 and 1.0

well suited Density ratio less than 0

Null density ration is assigned to the “not rated” class.

Derivation

base table component.

# Retrieves the maximum of a bulk density ratio 0cm to bedrock, or to 150 cm. The maximum bulk density ratio is for that portion of each horizon in the depth range.

EXEC SQL select hzdept\_r, hzdepb\_r, sandtotal\_r, silttotal\_r, claytotal\_r, dbthirdbar\_r, taxorder, hzname

from component

INNER JOIN chorizon ON chorizon.coiidref=component.coiid and hzdepb\_r > hzdept\_r;

SORT BY hzdept\_r, hzdepb\_r

AGGREGATE column dbthirdbar\_r none, claytotal\_r none, silttotal\_r none, sandtotal\_r none, hzname none,

hzdept\_r none, hzdepb\_r none.

# Determine the LAYER THICKNESS IN RANGE; ABOVE A RESTRICTIVE LAYER.

DERIVE depth from rv using "NSSC Pangaea":"DEPTH TO BEDROCK OR CEMENTED LAYER".

DERIVE layer\_thickness from rv using "NSSC Pangaea":"LAYER THICKNESS IN RANGE; ABOVE A RESTRICTIVE LAYER" (0,30).

#DERIVE o\_thickness from rv using "NSSC Pangaea":"THICKNESS OF SURFACE ORGANIC HORIZON".

#derive in\_range from layer\_thickness using "NSSC Pangaea":"HORIZON THICKNESS IN RANGE" (0,30).

#"idealbd" is a calculated "ideal" bulk density for various combinations of sand, silt, and clay.

#"delta" accounts for the sliding scale of differences between ideal and actual bulk density at various s, si, &c contents.

#"densrat" is the ratio of the observed density difference to that density difference that shows that the density is limiting.

# Sum the Bulk density by horizon and compute weighted average.

define idealbd (((sandtotal\_r\*1.65)/100)+((silttotal\_r\*1.30)/100)+((claytotal\_r\*1.25)/100)).

define delta ((0.001911\*sandtotal\_r)+(0.002912\*silttotal\_r)+(0.0020151\*claytotal\_r)).

#Delta is the amount of compaction a soil layer can have before the root-limiting threshold is passed.

#If the difference between the actual and ideal bulk density exceeds delta, the layer is root limiting.

#Thus, if the density ratio (densrat) exceeds 1, the layer is definitely root limiting.

define differ ((dbthirdbar\_r)-(idealbd)).

define densrat (differ/delta).

ASSIGN densrat if hzname imatches "\*O\*" then 0 else densrat.

# Find minimum of restriction depth and 200cm

DEFINE min\_depth depth < 31 and not isnull(depth) ? depth : 31.

DEFINE in\_range isnull (hzdepb\_r) ? hzdepb\_r : hzdepb\_r <= min\_depth ? 1 : (hzdept\_r == 0 and hzdepb\_r - hzdept\_r >= min\_depth) ? 1 : 0.

DEFINE default 1/0.

define rv arraymax(lookup(1, in\_range, densrat)).

8. Clay content – Clay sized particles in soil provide surface area for organisms to live on.

Property used: WTD\_AVG CLAY CONTENT 0-30cm OR ABOVE RESTRICTION

Suitability limits:

poorly suited Clay content less than 30 percent

moderately suited Clay content between 30 and 40 percent

well suited Clay content greater than 40 percent

Null density ration is assigned to the “not rated” class.

Logic Diagram, Main Rule



Logic Diagram, Water Relations Sub-rule

