Classification of Permafrost Soils

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The current definitions and taxonomic keys in Soil Taxonomy (Soil Survey Staff, 1975) and Keys to Soil Taxonomy (Soil Survey Staff, 1987) do not adequately address many of the cryic and pergelic soils of high latitudes. As stated throughout Soil Taxonomy and Conversations in Soil Taxonomy (Smith, 1986), the existing concepts on soils of high latitudes are tentative and need to be revised as research continues. Progressive soil surveys are bearing these statements true. The use of current Soil Taxonomy concepts on many high-latitude soils with permafrost does not adequately aid the transfer of soil knowledge. Rather, these soils are being best fit into classes that ignore their unique and dynamic properties. This paper presents proposed amendments to Soil Taxonomy that would more accurately classify those high-latitude soils having permafrost.

Permafrost Soils

As defined in Soil Taxonomy, permafrost is a layer in which the temperature is perennially at or below 0°C, whether consistence is very hard or loose. Soils with permafrost have pergelic temperature regimes [mean annual soil temperature (MAST) <0°C] and are placed in pergelic subgroups. It is important to note that pergelic and permafrost are not synonymous. A soil with MAST <0°C may not have a temperature perennially below 0°C.

Permafrost soils are encountered consistently in arctic northern Alaska (zone of continuous permafrost) and sporadically in subarctic interior Alaska [zone of discontinuous permafrost (Pewe, 1975)]. Soil Taxonomy currently treats the permafrost soils from these two zones identically. In reality, however, the two zones differ in the processes affecting the presence of permafrost in soil, and in the management implications of that permafrost.

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In a general overview, soils from the northern arctic region that currently classify in pergelic subgroups have permafrost within 40 in. This is true regardless of the thickness of the surface organic mat. The soil temperature and permafrost are the dominant soil properties affecting use and management. Management is usually directed at preserving the existing level of permafrost.

In the interior subarctic region, a dynamic relationship exists between the surface organic mat thickness, soil temperature, and depth to permafrost. Many soils, under climax native vegetation, have a thick layer of mosses and organic matter on the surface. This organic mat acts as an effective insulator against changes in soil temperature. The soil temperature is perennially <0°C in these soils. If the surface organic mat is disturbed, either by people, or more commonly, by wildfire, the soil temperature will begin to rise and the permafrost table will lower. If the disturbance is significant, MAST may, within a few years, rise above 0°C (Fig. 1) and the permafrost table recede to well below 40 in. Pergelic soils, often impermeable and with a perched water table, have altered to cryic soils of varying permeability. With natural succession of the vegetation toward climax, the surface organic mat will reestablish and thicken, and the MAST will decrease below 0°C again. The permafrost table will rise in the profile again as the soil temperature is maintained continuously below 0°C. The full cycle has been estimated at 50 to 70 yr (Viereck, 1973; Foote, 1976) and all stages of the cycle can be

Fig. 1. Relationship of mean annual soil temperature (MAST) and vegetative cover for the Copper River series. Sites are in close proximity on the same landform. The Spruce site is in a late seral stage. The Aspen site is in an early seral stage because of wildfire. The field site was cleared for agriculture.
Fig. 2. Cycle of a subarctic permafrost soil. All points of the cycle may be represented on the landscape. Current taxonomic class: frozen—loamy, mixed, nonacid Histic Pergelic Cryaquept; thawed—coarse-silty over clayey, mixed, nonacid Typic Cryochrept.

represented across a landscape at a given time. Depending on the severity of disturbance (e.g., intensity of burn), or the overlapping of disturbances, the cycle can be entered or interrupted at any stage. This cyclic relationship between vegetation, soils, and permafrost in the subarctic is well documented in the literature (Kallio and Rieger, 1969; Viereck and Schandelmeier, 1980; Ping, 1987). Management is directed, in some cases, at preserving the permafrost level, and, in others, at lowering it.
Soil Taxonomy and historical mapping concepts do not adequately address the cyclic nature of these subarctic soils. Using the current classification keys, soils at the extreme ends of the cycle will classify differently. Using the current keys, a soil may classify as a loamy, mixed, Histic Pergelic Cryaquept at one extreme of the cycle, and as a coarse-silty over clayey, Typic Cryochrept at the other (Fig. 2). These extremes, and all points of the transition exist on the same landscape, separated only by fire scars or human-vegetative disturbance. Any continuity or relationship between the stages of the cycle are lost using current classification concepts. The midrange of the cycle often becomes ignored, although it can be the dominant soil condition on the landscape. In surveys correlated to date, some frozen soils were mapped, described, and classified as frozen, yet interpreted as thawed. Others, obviously frozen, were mapped, described, classified, and interpreted as thawed. Some thawed soils were mapped, classified, and interpreted as frozen. At this point, valid correlation and interpretation are impossible.

In some surveys, an attempt was made to map and classify various stages of the cycle, e.g., Histic Pergelic Cryaquepts—Aeric Cryaquepts—Aquic Cryaquepts—Typic Cryochrepts. This method indirectly reflects the existence of the cyclic process, but fails to distinguish these soils from others that are not part of this cyclic process.

One of the desirable attributes for a soil taxonomy is that “the differentiae should keep an undisturbed soil and its cultivated or otherwise man modified equivalents in the same taxon insofar as possible” (Soil Survey Staff, 1975). We originally proposed that the same classification, down to the subgroup, be used for all stages of a cyclic permafrost soil. Interpretive phases would be used in mapping to separate the frozen and thawed counterparts. This is not always possible, since, in some cases, soil properties such as moisture regime and diagnostic epipedons significantly change through the cycle.

Control Section

The existing family and series control section criteria in Soil Taxonomy also do not allow for adequate classification for management interpretations of permafrost soils. The present family criteria is as follows (Soil Survey Staff, 1987): (i) 0 to 14 in., if the permafrost level is within 14 in. of the mineral surface, or (ii) 10 in. or to 10 in. below the permafrost level 2 months after the summer solstice or 40 in., whichever is shallower. The series control section is from the mineral surface to 40 in. or to 10 in. below the permafrost level 2 months after the summer solstice, whichever is shallower.

These criteria are adequate in the arctic where management is geared toward maintaining the permafrost level. Here, soil temperature and permafrost are the major limiting properties of a soil. In the subarctic, however, the permafrost table will rise and lower in response to the insulating properties of the organic mat. Thus, the control section and family classification can change as the surface organic mat is impacted by disturbance. This change is most obvious in soils with strongly contrasting particle classes within 40 in. Also, in the subarctic, the management goal is often to lower the permafrost level, usually by disturbing or removing the organic mat. As such, particle-size, mineralogy, reaction class, and other key properties, in both the surface and subsoil become important for classification, interpretation, and management.
Using current-control section criteria, most subarctic soils with permafrost close to the surface can be classified in only a limited number of families. This is compounded by the fact that many interior Alaska soils consist of silty eolian material overlying various substrata. Few series are recognized since the family and series control sections often do not extend below the loess mantle. Yet, for interpretation and management, the soils need to be classified based on properties to 40 in. Presently, one series may cover several landforms and includes such a range in substratum properties as to provide little useful information for interpretation and management.

Proposals

Listed below are proposals to improve the taxonomic classification of permafrost soils.

1. Control-section:
   In subarctic soils, do not consider permafrost when defining the family and series control sections. The family control section should be 10 to 40 in. The series control section should be the mineral surface to 40 in.

2. Pergelic temperature regime:
   Change the definition of the pergelic temperature regime to "Soils having soil temperature perennially below −5°C." These soils would occur within the zone of continuous permafrost (Pewe, 1975), which roughly coincides to the arctic region.

3. Subgroups of cryic great groups:
   a. Add a "gelic" subgroup to Soil Taxonomy. Gelic subgroups of cryic great groups would be those "soils with a soil temperature perennially between 0 to −5°C under undisturbed climax native vegetation. Significant disturbance of the surface organic mat will result in an increase in soil temperature with MAST increasing above 0°C. If the disturbance is not permanent, the organic mat will re-establish and thicken, the MAST will decrease below 0°C, and the permafrost table will begin to rise again."

   Histic gelic subgroups would not be used. The gelic subgroup would recognize the cyclic presence of a histic epipedon.

   The following subgroups would be necessary: Gelic Cryorthents, Gelic Cryaquents, Gelic Cryochepts, Gelic Cryaquepts, Gelic Cryumbrepts, Gelic Crysquolls, and Gelic Cryoborolls. The following subgroups may be needed in the future: Gelic Cryaquods, Gelic Sideric Cryaquods, and Gelic Cryorthods.

   b. Pergelic subgroups would follow the proposed definition of pergelic temperature regime. They would pertain to those soils where soil temperature is below −5°C. These soils would retain the permafrost table within the profile despite disturbance of the organic mat.
Application

Soils in the subarctic region would be classified based on their existing morphological properties and their temperature under climax native vegetation, that is, the extreme frozen end of the cycle. As a general rule, the average temperature of permafrost, at a depth where seasonal temperature change is minimal, is close to the average temperature of the ground surface and 2 to 6 °C warmer than the mean annual air temperature (Lachenbruch, 1970).

A map unit containing a permafrost soil would have a range in depth to permafrost of 0 to 40 in. The actual range for the named component would be narrower, with the similar inclusions taking up the full range. The soil would be classified in a gelic subgroup. The classification at the great group level and higher would be based on existing soil properties. As an example, a soil at the frozen end of the cycle might classify as a Gelic Cryaquert. The map unit would provide interpretations for the frozen soils as well as potential interpretations for the soil if it were thawed. The actual interpretations provided would be dependent on the amount of substratum data available.

Pedons where the organic mat was disturbed and the permafrost level dropped below 40 in. would also be classified in a gelic subgroup. Again, the great group and higher classification would be based on existing properties. Using the above example, the soil might remain a Gelic Cryaquert or classify as a Gelic Cryochrept, depending on the thawed morphology. If the classification remained the same, a thawed interpretive phase would be used. The range in depth to permafrost in a map unit containing this component would be 40 in. to more than 60 in. (range for both component and similar inclusions).

The proposed changes to Soil Taxonomy will allow the process of permafrost cycling to be recognized at the subgroup level. The changes will also allow substratum properties to be recognized for both classification and interpretive purposes. This approach will allow the user to visualize and understand the soil processes occurring in the survey area. As such, Soil Taxonomy will be a useful tool in the transfer of soil knowledge regarding permafrost soils. These proposals have been submitted to the National Cooperative Soil Survey for review and consideration.

References


Progress in Professionalism

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Abstract

The American Registry of Certified Professionals in Agronomy Crops and Soils (ARCPACS) became operational in 1977 as a credentialing organization for agronomists, crop scientists, and soil scientists. This is a report of the progress and accomplishments of ARCPACS since 1977. The ARCPACS Board of Directors has set minimum educational and experience requirements for certification, developed a program for credit by examination, and established a policy of continued education to maintain certification. Through the end of 1989, 2,991 individuals have been certified. Thirty-two organizations have accepted the ARCPACS purposes and code of ethics and become affiliated chapters. Thirty-two states or agencies have established laws or regulations regarding practice in the agronomic sciences, which emulate ARCPACS certification requirements; 13 states cite ARCPACS qualifying criteria in rules/regulations. Employers and governmental agencies use the ARCPACS Registry of Certified Professionals as a source of qualified practitioners.

The American Registry of Certified Professionals in Agronomy, Crops, and Soils (ARCPACS) is a member service of the American Society of Agronomy (ASA). Its purposes are:

1. To develop standards and procedures for recognition of persons qualified as professionals in agronomy, crops, and soils.
2. To maintain a registry of persons so qualified for the welfare of the general public.

The program came into being as a result of member demands for a professional credentialing program for agronomic scientists. A developmental history of ARCPACS has been presented elsewhere (Openshaw, 1980–1981)

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