



Predicted Soil Protein

The Autoclaved Citrate Extractable (ACE) Protein Index (Soil Protein) is an indicator of the amount of protein-like substances that are present in the soil organic matter. Soil protein represents the largest pool of organically bound nitrogen (N) in the soil organic matter, which microbes can mineralize and make available for plant uptake.

Beginning in 2020, the Cornell Soil Health Lab moved to **predict** Soil Protein from a suite of measured parameters in the Standard comprehensive assessment of soil health (CASH) package. The laboratory measured ACE Soil Protein assay will remain available to researchers and others as an optional add-on to the Standard CASH package.

Modeling Soil Protein

In 2020, the Cornell Soil Health lab determined that soil protein, a valuable, but time-intensive measurement, could be accurately predicted. A Predicted Soil Protein relationship was developed using a Random Forest model to predict soil protein level from a suite of measured parameters, including % sand, % silt, % clay, Organic Matter, Active Carbon, Total Carbon, Total Nitrogen, Tot C/Tot N, and pH. This model was able to explain 82.5% of the variation in protein with a low average root mean square error (RMSE) value (Fig. 1).

Random Forest (RF) is a robust machine learning algorithm that uses a decision tree approach to model variables. Machine learning algorithms such as RF have become increasingly popular techniques to model parameters that are difficult or costly to measure. Environmental scientists have developed models using routinely measured parameters to predict difficult or costly to measure soil properties such as soil nitrogen availability to crop plants.

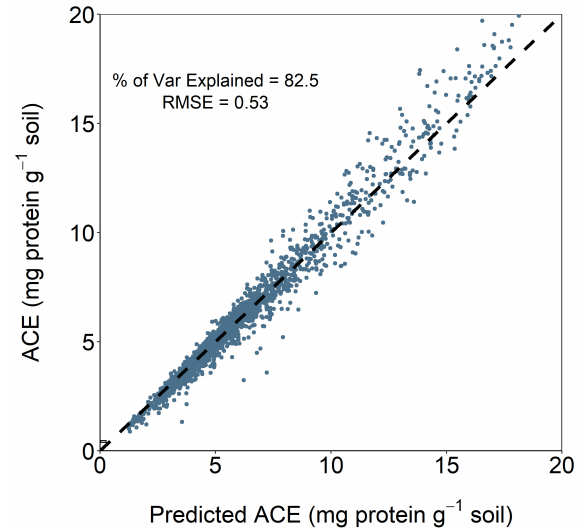


FIGURE 1. Predicted Protein content vs. observed Protein content for the CASH database (n=2,798).

How soil protein relates to soil function

Plant residues are ultimately the source of much of the soil organic matter. Residues are made up of several types of compounds that are largely similar in composition (Fig. 2). Of these compounds, protein contains the largest fraction of N.

Protein content, as organically bound N, influences the ability of the soil to store N, and make it available by mineralization during the growing season. An active microbial population is responsible for for this change from organic N to plant available N. Soil protein content has also been associated with soil aggregation and thus water storage and movement.

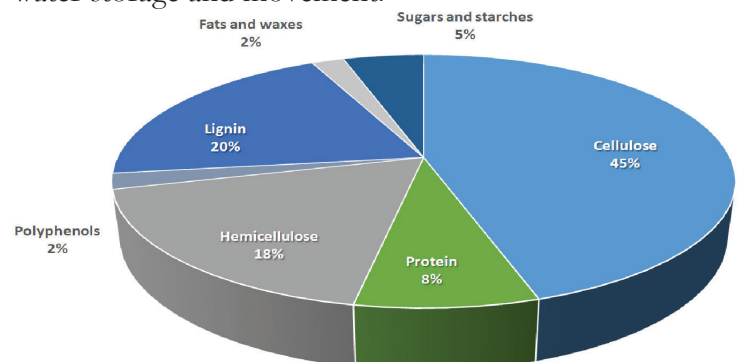


FIGURE 2. Types of compounds in plant residues. Proteins are found in high abundance and contain the largest N fraction. Modified from Brady and Weil (2002)

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Managing constraints and maintaining optimal soil protein content

To store and maintain N in soil organic matter, we need to accumulate compounds that are relatively stable, rich in N (low C:N ratio), microbially degradable, and potentially abundant in amendments, crops, cover crops, or residues (Fig. 3). Building and maintaining healthy, biologically active soil with large reserves of decomposing plant tissue in organic form is a good approach to provide a crop with its N needs over time as opposed to applying soluble forms of N that plants may not use immediately and be lost. Organic forms of N reserves are built over years and should be maintained to the extent possible.

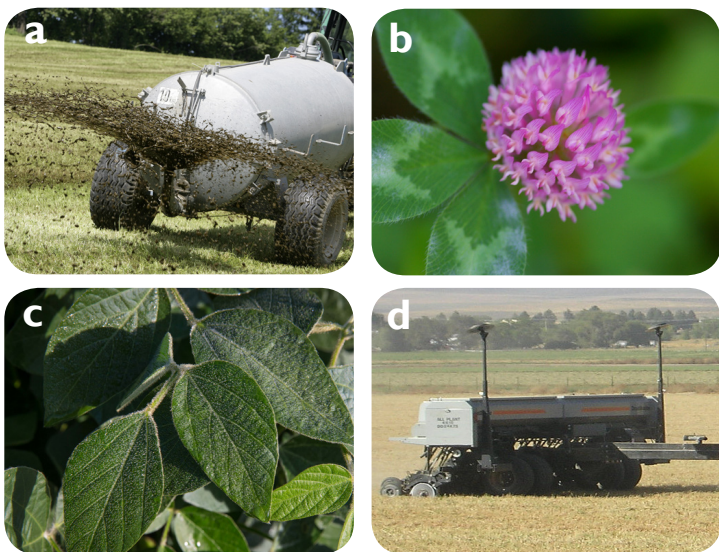


FIGURE 3. a - d. SOM building practices. **Short term strategies:** (a) Manure (amendment), (b) Red clover (green manure cover crop), **Long term strategies:** (c) Soybeans (crop rotation), (d) No-till drill (reduced tillage). Photo source: Flickr

Protein content can be increased by adding organic amendments directly such as manure and well-finished compost high in N (Fig. 3). Cover crop mixtures using diverse species with useful root architecture provides green biomass grown in place to maintain the presence of living, actively growing roots. Well nodulated legumes are important sources of root zone N to sustain a large microbial population. Most of these sources are slow to release N over time which can reduce environmental losses. Use careful planning to reduce tillage intensity and to enable timely no-till drilling of cover crops. Protein content tends to decrease with increasing soil disturbance such as tillage.

Scoring function

Figure 4 below depicts the **predicted** Soil Protein scoring functions and upper value limits for coarse, medium, and fine textured soils. It is important to note that extremely high N mineralization could increase losses of N to the environment and thus harm air and water quality. The red, orange, yellow, light green and dark green shading reflects the color coding used for the ratings on the soil health report summary page.

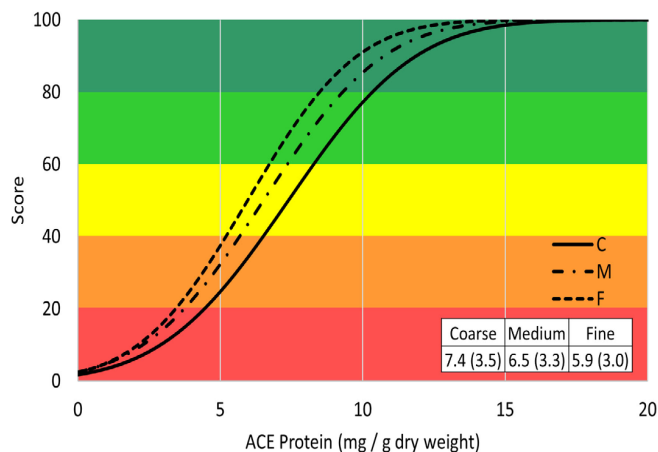


FIGURE 4. **Predicted** Soil Protein Index scoring functions and upper value limits for Coarse (C), Medium (M) and Fine (F) textural classes. Mean and standard deviation (in parenthesis) for each class are provided. In this case more is better. Higher protein index scores indicate a larger pool of organically-bound soil N.

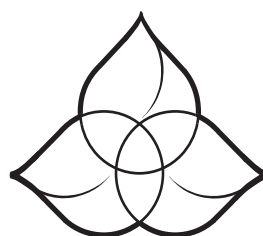
Cornell Soil Health Laboratory ACE Protein [Standard Operating Procedures](#) (CSH 07) can be found under the 'Resources' tab on our website.

For a more comprehensive overview of soil health concepts including a guide on conducting in-field qualitative and quantitative soil health assessments, please download the Cornell Soil Health Manual at bit.ly/SoilHealthTrainingManual

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