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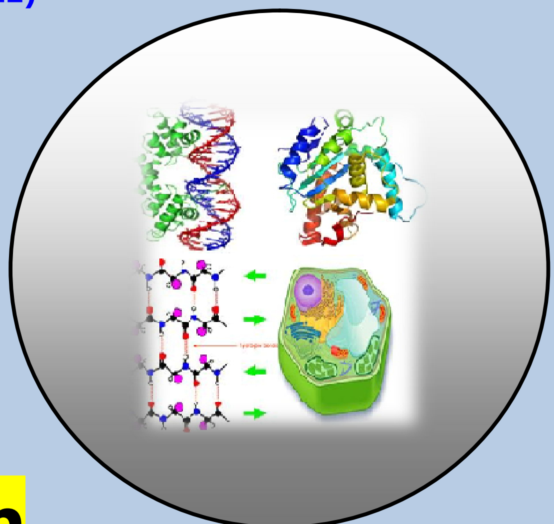

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REVIEW ARTICLE

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Sources of Soil Enzymes

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ABSTRACT

Enzymes are complex proteins that cause a specific chemical change in all parts of the body. Enzymes have interesting properties. Soil quality is the ability of a soil to perform functions that are essential for biotic factors and environment. Soil quality is not limited to agricultural soils, although most soil quality work has been done in agricultural systems. Soil enzyme activities are the direct expression of the soil community to metabolic requirements and available nutrients. While the diversity of soil organisms is important, the capacity of soil microbial communities to maintain functional diversity of those critical soil processes through disturbance, stress or succession could ultimately be more important to ecosystem productivity and stability than taxonomic diversity. This review examines selected papers containing soil enzyme data that could be used to distinguish enzyme sources and substrate specificity, at scales within and between major nutrient cycles. Developing approaches to assess soil enzyme functional diversity will increase our understanding of the linkages between resource availability, microbial community structure and function, and ecosystem processes.
Key words: Enzyme, Soil, Indicators, Community and Diversity.

Soil Quality Assessment

Soil quality cannot be measured directly because it is a broad, integrative, context-dependent concept. Instead, we analyze a variety of proxy measurements that together provide clues about how the soil is functioning as viewed from one or more soil-use perspectives. These measurements are called soil quality indicators.

A set of low-cost readily measured indicators that accurately predict soil functions of interest is called an efficient indicator set. Indicators of soil quality may include characteristics of soil solids, soil solutions, soil atmospheres, vegetation, and other soil biota, and possibly even economic analyses of land-uses or ecosystem services.

Although the quantity and quality of data may differ, the process of soil quality evaluation follows the same basic steps regardless of the method used: identification of soil use issues followed by indicator selection and interpretation. More specifically, in order to select appropriate indicators, one must first determine the land-use objectives, and then indicators must be proposed, measured and assessed across a representative set of lands and management practices. An efficient indicator set should be used to inform land management decisions at specific sites and then be used to monitor trends in soil function after changing practices and over time

Soil Enzymes

What it is: Soil enzymes increase the reaction rate at which plant residues decompose and release plant available nutrients. The substance acted upon by a soil enzyme is called the substrate. For example, glucosidase (soil enzyme) cleaves glucose from glucoside (substrate), a compound common in plants. Enzymes are specific to a substrate and have active sites that bind with the substrate to form a temporary complex. The enzymatic reaction releases a product, which can be a nutrient contained in the substrate. Sources of soil enzymes include living and dead microbes, plant roots and residues, and soil animals. Enzymes stabilized in the soil matrix accumulate or form complexes with organic matter (humus), clay, and humus-clay complexes, but are no longer associated with viable cells. It is thought that 40 to 60% of enzyme activity can come from stabilized enzymes, so activity does not necessarily correlate highly with microbial biomass or respiration. Therefore, enzyme activity is the cumulative effect of long term microbial activity and activity of the viable population at sampling. However, an example of an enzyme that only reflects activity of viable cells is dehydrogenase, which in theory can only occur in viable cells and not in stabilized soil complexes. ()

Why it is important: Enzymes respond to soil management changes long before other soil quality indicator changes are detectable. Soil enzymes play an important role in organic matter decomposition and nutrient cycling (see table 1). Some enzymes only facilitate the breakdown of organic matter (e.g., hydrolase, glucosidase), while others are involved in nutrient mineralization (e.g., amidase, urease, phosphatase, sulfates). With the exception of phosphatase activity, there is no strong evidence that directly relates enzyme activity to nutrient availability or crop production. The relationship may be indirect considering nutrient mineralization to plant available forms is accomplished with the contribution of enzyme activity. Specific problems that might be caused by poor function: Absence or suppression of soil enzymes prevents or reduces processes that can affect plant nutrition. Poor enzyme activity (e.g., pesticide degrading enzymes) can result in an accumulation of chemicals that are harmful to the environment; some of these chemicals may further inhibit soil enzyme activity.

What you can do: Organic amendment applications, crop rotation, and cover crops have been shown to enhance enzyme activity (figures 1 and 2). The positive effect of pasture (figure 2) is associated with the input of animal manure and less soil disturbance. Agricultural methods that modify soil pH (e.g., liming) can also change enzyme activity

Measuring soil enzymes: Enzymes are measured indirectly by determining their activity in the laboratory using biochemical assays. Enzyme assays reflect potential activity and do not represent true in situ activity levels and must be viewed as an index.

When possible, compare the site of interest to samples taken from an adjacent, undisturbed site on the same soil type. Alternatively, for a newly implemented land management system, track changes from time zero to fiveor more years with annual sampling to detect temporal changes in activity of soil enzymes.

Soil Reaction Indicators including soil pH

Soil is the major "switching yard" for the global cycles of carbon, water, and nutrients. Carbon, nitrogen, phosphorus, and many other nutrients are stored, transformed, and cycled through soil.

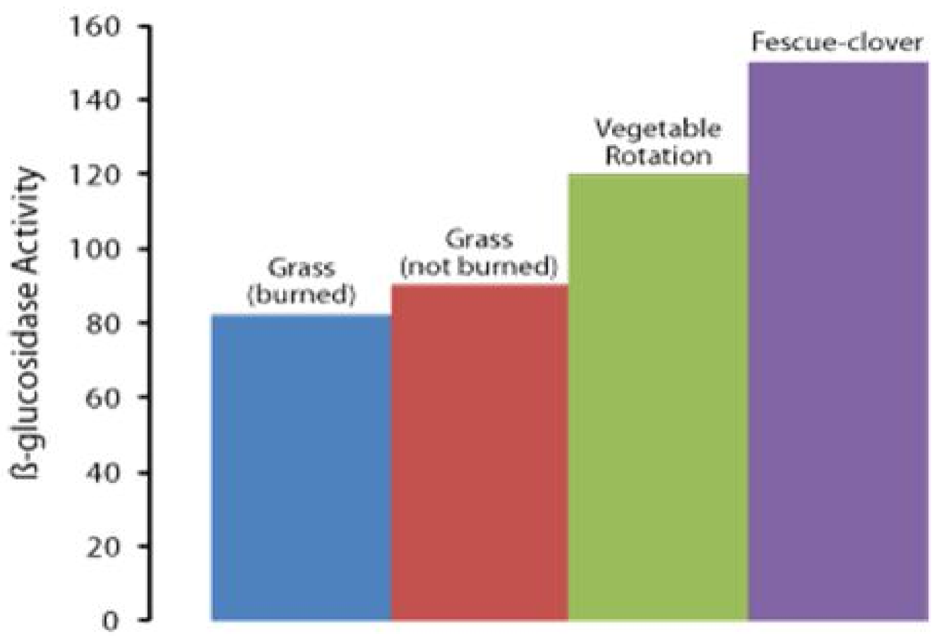


Figure 1. Effects of cropping systems on ß-glucosidase (adapted from Dick 1994).

Decomposition by soil organisms is at the center of the transformation and cycling of nutrients through the environment. Decomposition liberates carbon and nutrients from the complex material making up life forms-putting them back into biological circulation so they are available to plants and other organisms. Decomposition also degrades compounds in soil that would be pollutants if they entered ground or surface water. (Bandick and Dick, 1999)

Decomposition is a stepwise process involving virtually all soil organisms. Arthropods and earthworms chew the material and mix it with soil. A few fungi may break apart one complex compound into simpler components, then bacteria can attack the newly created compounds, and so on. Each organism gets energy or nutrients from the process. Usually, but not always, compounds become simpler after each step. The portion of plant and animal residue that is not broken down plays a crucial role in soil. It is transformed into the highly complex organic compounds called humic substances that can persist in soil for centuries and are important to soil structure and nutrient storage.

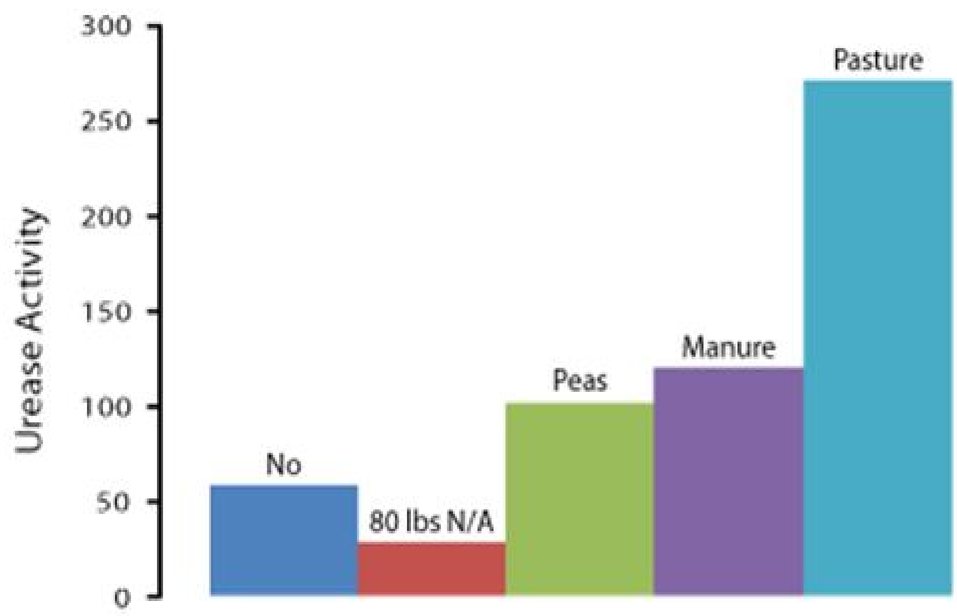


Figure 2. Effects of management on urease activity (adapted from Bandick and Dick 1999).

Table 1. Role of soil enzymes

Enzyme	Organic Matter Substances Acted On	End Product	Significance	Predictor of Soil Function
Beta glucosidase	carbon compounds	glucose (sugar)	energy for microorganisms	organic matter decomposition
FDA hydrolysis	organic matter	carbon and various nutrients	energy and nutrients for microorganisms, measure microbial biomass	organic matter decomposition nutrient cycling
Amidase	carbon and nitrogen compounds	ammonium (NH4)	plant available NH4	nutrient cycling
Urease	nitrogen (urea)	ammonia (NH3) and carbon dioxide (CO2)	plant available NH4	nutrient cycling
Phosphatase	phosphorus	phosphate (PO4)	plant available P	nutrient cycling
Sulfatase	sulfur	sulfate (SO4)	plant available S	nutrient cycling

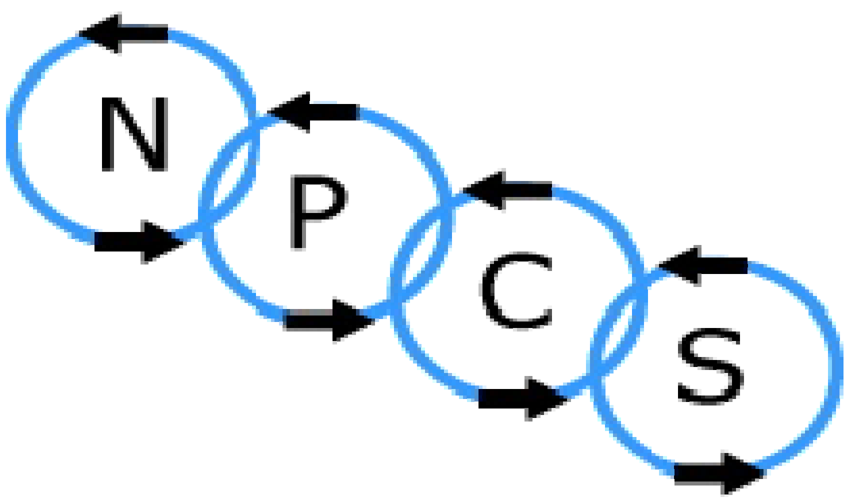
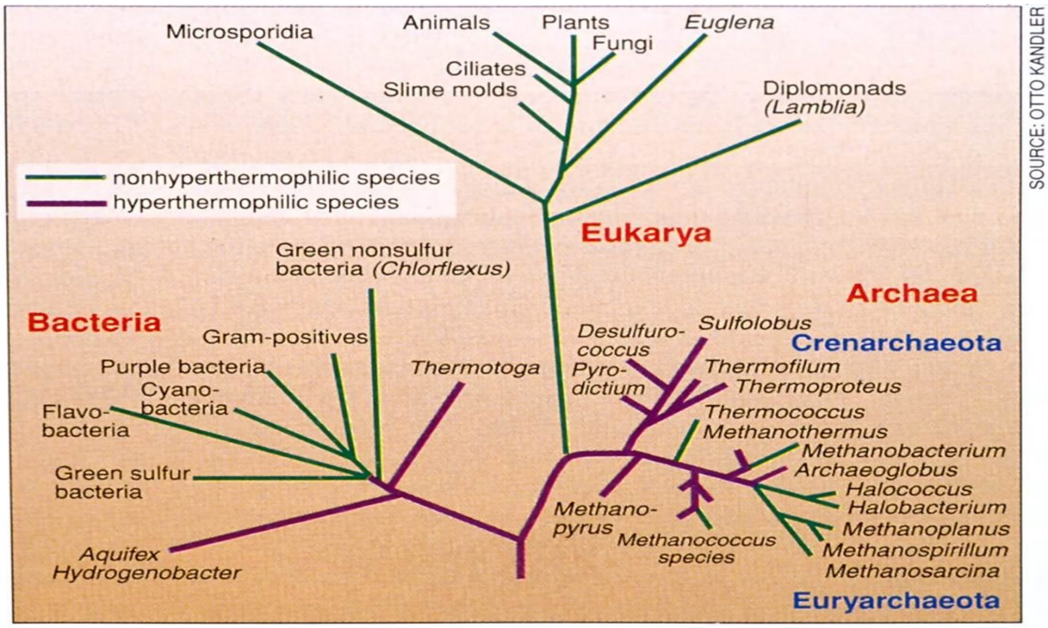


Fig 3. Nutrient cycling can be assessed by measuring the following indicators.

Sources……………………………………Enzymes Keyrodin, 2014



Tree of life. The Woese family tree shows that most life is one-celled, and that the oldest cells were hyperthermophiles.

Fig 4. Availability of N from organic sources is the outcome of diverse enzymatic processes comprising N mineralization, immobilization and nitrification.

Carbon Dioxide and Soil

The carbon cycle illustrates the role of soil in cycling nutrients through the environment. More carbon is stored in soil than in the atmosphere and above-ground biomass combined. Soil carbon is in the form of organic compounds originally created through photosynthesis in which plants convert atmospheric carbon dioxide (CO_2) into plant matter made of organic carbon compounds, such as carbohydrates, proteins, oils, and fibers. The organic compounds enter the soil system when plants and animals die and leave their residue in or on the soil. Immediately, soil organisms begin consuming the organic matter, extracting energy and nutrients and releasing water, heat, and CO_2 back to the atmosphere. (Dick, 1994). Thus, if no new plant residue is added to the soil, soil organic matter will gradually disappear. If plant residue is added to the soil at a faster rate than soil organisms convert it to CO_2, carbon will gradually be removed from the atmosphere and stored (sequestered) in the soil. Cultivation aerates the soil, triggering increased biological activity, and therefore rapid decomposition, loss of soil organic matter, and release of CO_2 into the atmosphere. Most soil carbon losses occur in the first several years after cultivation begins, as took place in many U.S. soils in the 1800's. Farmers and other conservationists are interested in reversing that effect and increasing the amount of carbon stored in the soil.

In general, reducing tillage can increase the extent of carbon sequestration and the amount of organic matter retained in the soil stores, moderates the release of, and cycles nutrients and other elements. During these biogeochemical processes, analogous to the water cycle, nutrients can be transformed into plant available forms, held in the soil, or even lost to air or water. (Tabatabai, 1994).

Nutrient cycling can be assessed by measuring the following indicators

Fertility Indicators including mineral nitrogen, potentially mineralizable nitrogen, soil nitrate, soil test phosphorus, potassium, sulfur, calcium, magnesium, boron, and zinc

Organic Matter Indicators including C: N ratio, decomposition, microbial biomass carbon, particulate organic matter, soil enzymes, soil organic matter, total organic carbon and total organic matter Soilquality.org depends on content contributions from soil quality scientists and practitioners. In many cases, articles follow an easy-to-populate template. In all cases, peer review gives authors on-line publication credit for their contributions and an incentive to provide additional content. If you see an area where you can contribute, please contact the Web Content Manager for more information.

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Value of Soil

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- Greenhouse gases
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- Sustainability
- Aesthetics

Types of Soil Quality Assessment Tools

Qualitative Scorecards - provide lists of observable soil indicators (often developed by farmers) that are qualitatively evaluated by land managers repeatedly over time to monitor changes in quality. Visit the NRCS Soil Quality web site for more information on qualitative scorecards and state examples. Field Test Kits - refers to any suite of in-field soil tests conducted by land managers to provide semi-quantitative data. Kits have been developed in the U.S., New Zealand and Australia. See Soil Quality Test Kit for more information and support tools. Lab-based assessments - assessments based on indicators requiring more specialized equipment or more precise measurement than possible with field test kits, such as microbial biomass carbon, soil test phosphorus or potentially mineralizable nitrogen. These include the Soil Management Assessment Framework available at this web site and the Cornell Soil Health Assessment. Practice Predictors - use research outcomes to predict the effects of management practices on soil quality. The NRCS Soil and Water Eligibility Tool (SWET) and Conservation Measurement Tool (CMT), are examples of this type of assessment tool.

Landscape-level assessments - use satellite and remote sensing technology to assess resource quality at large spatial scales. Using remote sensing to predict soil carbon storage is one possible use for this type of assessment. Multi-factor sustainability tools, which combine environmental, economic and social indicators, are a logical outgrowth from soil quality assessment of agroecosystems due to the important relationship between soil quality and sustainability. These include a proposed Sustainability Index. Novel methods for the examination of microorganisms responsible for N turnover will be developed and will enable description of the microbial community responsive to contrasting N sources and quantities. Our goal is to describe functional diversity in the root-zone of microbial communities responsible for selected N transformations in agroecosystems under contrasting nitrogen management. We will extract microbial DNA and mRNA from soil sampled from existing experimental systems in Utah and Georgia. Functional diversity of the genes encoding enzymes will be examined using molecular tools including PCR and clone libraries, 454 sequencing of tagged clone libraries and real-time PCR in association with measurements of N transformation rates and enzyme kinetics. Using functionally targeted meta genomic surveys of soil DNA, we will recover and characterize novel bacterial and fungal genes encoding key enzymatic functions in N transformations. The role of bacterial and archaeal ammonia oxidizers in soil nitrification will be further delineated. Knowledge of diversity in the genes encoding enzymes responsible for N cycling will strengthen our understanding of microbial controls on N availability to plants. Improved understanding of microbial N cycling will aid in the development of agricultural systems with enhanced N cycling efficiency and promote food security.

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