Guidance Document

Guidance for Implementing Soil Carbon Amendment (Code 336)

Purpose and Scope

The purpose of this guidance document is to streamline the conservation planning process when implementing Conservation Practice Standard Soil Carbon Amendment (Code 336).

Many of Missouri's soils are low in soil organic matter, biological activity, and carbon. Much of this loss can be attributed to historical farming practices that included intense tillage, low crop diversity, intense grazing, and low or no residue returned to the soil. Many soils in the state are considered "eroded" and have little topsoil or desired biological soil function left.

Conservation Practice Standard (CPS) Soil Carbon Amendment (Code 336) was developed to add carbon amendments to soils. Applying this conservation practice will not fix all degraded soils and sites, but CPS Soil Carbon Amendment (Code 336) can be used in conjunction with other conservation practices to improve soil and biological health and function.

Soil Carbon Amendment Testing

Testing of soil properties is required prior to planning the application of a soil carbon amendments. Soil testing parameters are listed within CPS Soil Carbon Amendment (Code 336). Testing is required to ensure the appropriate carbon amendment can be applied to address the resource concern without creating further concerns. Carbon amendments are highly variable in properties. Properties will differ based on the feedstock materials, temperatures, moisture, and other factors. Applying the incorrect amendment to soils may cause additional resource concerns or make existing concerns worse.

Soil testing will be done in accordance with CPS Nutrient Management (Code 590) testing procedures. Soil testing labs will need to meet current requirements and performance standards of the Missouri Soil Testing Association accreditation program to ensure accuracy of soil test results as a minimum for applying nutrients for crop or forage production.

Soil carbon amendments will be analyzed by Test Methods for the Examination of Composting and Compost (TMECC) for composted materials and International Biochar Initiative (IBI) standards when applying biochar. All soil carbon amendments must meet the testing requirements which are defined within CPS Soil Carbon Amendment (Code 336). Few labs test for all the parameters listed in Tables 1, 2, and 3 of the CPS Soil Carbon Amendment (Code 336). Samples may require submission to multiple labs or have multiple tests performed to get the required parameters.

Vendors selling carbon amendments need to provide laboratory tests which meet the CPS Soil Carbon Amendment (Code 336) requirements when soil carbon amendments are purchased. The US Composting Council has a listing of current Seal of Testing Assurance Program (STA) compost-certified laboratories. The International Biochar Initiative lists labs under the IBI Biochar Certification Program; vendors will provide the information listed on the IBI Laboratory Test Form.

Compost

Composting is a mixture of organic wastes used as a soil carbon amendment to improve soil's physical, chemical, and biological properties. The compost decomposes to form a uniform and stable finished product which contains soluble nutrients and humic compounds. There are multiple types and methods of composting to achieve different finished compost products with different properties.

Microorganisms complete most of the composting under elevated temperatures with oxygen and moisture. The compost-adapted organisms live within temperature ranges up to 130°F. Temperatures above 160°F can develop during the compost process which help kill weed seeds and disease organisms not able to tolerate high temperatures. Anything that inhibits air flow, maintaining sufficient moisture, or maintaining high enough temperatures (greater than 110°F) can slow or impede the composting process.

The ideal moisture content of the composting material is 40 to 60 percent. When the pile dries to less than 35 percent moisture, ammonia is lost as a gas and beneficial organisms don't repopulate. Very dry composts will become populated with molds instead of beneficial organisms.

Piles which are too wet may become anaerobic. Anaerobic composting occurs when microorganisms which do not require oxygen to survive are predominately present. Piles in this condition often have odors and attract flies. Since oxygen is limited, the piles will heat to a temperature high enough to safely kill pathogens and weed seeds. Anaerobic composts will not be acceptable for uses to add carbon to soils. Anaerobic composts may be blended with other organic wastes and composted through an aerobic process to meet the compost requirements.

Organic matter contained within compost can range from 30 to 70 percent. In addition to organic matter, compost will contain biologically stable macro and micronutrients. Mature compost will not have odors associated with ammonia, organic acids, or other water-soluble compounds which may inhibit plants when land applied.

To produce a stable compost, compost products must go through heat cycles. There are many resources available for how to produce a stable nutrient dense compost. Those references may be used for more clarification.

Compost can be produced in piles, windrows, bins, or other structures. When compost is initially piled, with appropriate moisture and oxygen, the pile will heat. Once the interior of the pile has reached 140°F and allowed to stabilize, the pile can be mixed again. After a second mixing cycle the pile will reheat. The longer the stabilization period, the more stable the compost product will be when land applied. When fully processed, compost can be a valuable source of organic matter, nutrients, and biology.

Poultry litter is commonly used as a nutrient source in crop and pastures. Many poultry operations will bed the first flock with sawdust or shavings. When that flock is removed, operations may windrow the litter to allow it to compost inside the poultry house before the next flock is placed. Windrow composting may occur for 4 to 6 flocks before a total cleanout of all the litter. Litter from earlier flocks will have been through at least one composting cycle; however, litter from the last flock has not been through a compost cycle. To meet the CPS Soil Carbon Amendment (Code 336), litter will need to be further composted to meet the compost testing requirements listed in the standard. Testing will be done at the conclusion of the composting process. Poultry litter that is directly land applied at clean-out does not meet the compost requirements since it has not been properly composted. Instead, follow the CPS Nutrient Management (590) requirements for the proper application of the manure product.

Biochar

Biochar has been used for centuries for cooking, health, water purification, and soil improvement. Pyrolysis is the process of heating organic biomass (wood chips, manure, solid wastes) in the absence of oxygen which leaves a carbon rich product often referred to as "biochar". The International Biochar Initiative defines biochar as the solid byproduct of a thermochemical conversion process containing more than 10 percent carbon. The carbon in biochar is considered extremely stable in the environment. Most research indicates that biochar will last longer than 100 years in the soil depending on environmental conditions and management. Due to the long breakdown of biochar, it is often promoted as product to sequester carbon.

Biomass pyrolysis is usually conducted at or above 500^{o}C. Without oxygen, combustion does not occur. The biomass thermally decomposes into combustible gases and biochar. Most of these combustible gases can be condensed into a combustible liquid, called pyrolysis oil (bio-oil). Some permanent gases (CO_2, CO, H_2, and light hydrocarbons) are created and can be combusted to provide the heat for the process. Thus, pyrolysis produces three products: one liquid (bio-oil), one solid (biochar), and one gaseous (syngas). The proportion of these products depends on several factors including the composition of the feedstock and process parameters (temperature, oxygen, time). Biochar is usually the major product of slow pyrolysis.

Feedstock material and the conditions during pyrolysis all affect the biomass yield, carbon yield, pH, and particle size of the biochar. Biomass from feedstock material can be crop residues, shells, hulls, tree or shrub prunings, bagasse, wood chips, sawdust, or manure. Most of these materials are the waste product from a value-added processing step such as peanut hulls from a hulling plant or bagasse from sugar cane processing. The feedstock material will have direct impacts on the nature and quality of the biochar produced. Not all organic biomass is suitable for producing biochar. Waste products should not be used from household, municipal, or industrial sources or sources which may contain contaminants. The pyrolysis process can accumulate heavy metals and toxins that may contaminate soils. It is the manufacturer's responsibility to ensure that biochar feedstock materials are free from hazardous materials.

Yield of biochar is approximately 30 to 45 percent of the original biomass depending on temperature. As temperature increases, the carbon becomes more concentrated as a percent of the biomass while other nutrients decrease. Surface area and pH increase as temperature increases; however, the initial pH is highly dependent upon feedstock. The pH can range from very acidic to very basic depending on all conditions and variables.

Biochar weathering can occur when biochar is exposed to precipitation, ice, freeze/thaw cycles, temperature fluctuations, and other environmental factors. Weathering can significantly alter the biochar material properties by changing the physical and/or chemical properties. When biochar is stored outdoors, it is subject to more weathering than biochar stored in a controlled indoor environment. When biochar has been in long-term outdoor storage, a new test should be done to determine the physical and chemical changes prior to land application.

Biomass ash, bottom ash, and fly ash are all by-products of energy generation industry. While these products may be high carbon content products and have similar properties to biochar, they are not the same as biochar. These products may have accumulated toxics compounds and heavy metals during production. To use these products as biochar, the manufacturer must meet required documentation provided in the International Biochar Initiative provisions for High Carbon Biomass Ash.

Since biochar is a light carbon substance, there are safety concerns. When biochar has a low moisture content (less than 5 percent), it is very dry and can easily become air borne. Medium moisture content (less than 20 percent) is dry to the touch and is still unstable. When dry, biochar can easily ignite or combust and should be treated as a potential fire hazard. When moisture content of biochar is above 30 percent, the biochar is considered safe for handling, transportation, and storage. Individuals handling biochar should ensure personal protective equipment (PPE) is worn to prevent inhalation of dust. This is especially important at the lower moisture levels.

Biochar floats and thus should not be applied in floodplains or in areas of concentrated water flow. Planners should evaluate sites for flooding potential and avoid areas with slopes greater than 8 percent.

Biochar has a high surface area with high porosity which allows it to bind nutrients and improve water holding capacity in soils. Since most nutrients are lost in the pyrolysis process leaving carbon, biochar can tie up N and other nutrients within the soil when applied as a soil carbon amendment. “Charging” or “activating” the biochar is highly recommended prior to land application. Charging biochar is the process of physically mixing biochar with a nutrient source and allowing it time to stabilize. Charge or activate biochar with mixing it in compost or other nutrient rich materials two months prior to land application. Liquids fertilizer products may be used such as urine, compost tea, and lagoon water; biochar is very light and floats on liquids so a mixing apparatus may be needed to continually mix the biochar and liquid for three to four weeks. During that time, nutrients and biology will attach to the biochar and reduce the nutrient tie up at application time. When biochar is charged, testing should be done of the biochar with a separate test for the nutrient source.

Producers need to consider freight costs when purchasing biochar. Biochar weight is very dependent on moisture content. Since it is a very porous product, trucks will generally fill before they reach the maximum shipping weight. Thus, a full van trailer may not haul 20 tons. Often biochar is shipped in totes or super sacks which means the producer will need a way to handle those upon delivery.

Other Carbon Amendments

Other carbon amendments may include wood chips, bagasse, or by products from distillation processes. Many of these products have a high C:N ratio, are not decomposed, or have not started breakdown. To meet the CPS Soil Carbon Amendment (Code 336), these products need to be composted and meet the compost testing requirements listed above. When these products are not being processed and can be used as a high carbon mulch, refer to CPS Mulching (Code 484).

Planning of Soil Carbon Amendments

Soil carbon amendments can increase soil carbon and soil organic matter when appropriately applied. Knowing how a soil or field will respond to application of soil carbon amendments is difficult given the variability between soil carbon products. There is not a lot of university research on biochar; however, compost has been researched for various products with different parameters and different results. Planners using the 9-step planning process in conjunction with producer information and product data should be able to determine if soil carbon amendments will be beneficial.

Planners should inventory the current operation and the root cause of the resource concern. Planners can use producer interview, observations, In-Field Soil Health Assessment (IFSHA) (cropland only), soil tests (cropland and pasture), or Pasture Condition Scores (PCS) to identify a concern.

Web Soil Survey contains a rating for Dynamic Soil Properties Response to Biochar Application under the Soil Data Explorer Tab>Suitabilities and Limitations for Use>Soil Health menu. The dynamic properties associated with the area of interest include pH, cation exchange capacity, water holding capacity, bulk density, hydraulic conductivity, and organic matter content which may be improved by the application of biochar. However, the degree of improvement is dependent upon how poor the current soil condition is. Less healthy sites are more likely to improve than healthy sites. The ratings indicate the suitability of a soil response to biochar applications. A rating of 1.00 indicates the greatest theoretical positive response while a rating of 0.00 indicates biochar applications will not improve soil dynamic properties. Some conditions may exist which limit the site rating due to limitations in biochar application or use such as slope, ponding, flooding, karst, or rock fragment content. Survey ratings are only based on dynamic soil properties and do not account for land use, vegetation, fertility, current or past management, and many other things that should be inventoried prior to determining if biochar will be beneficial. The ratings within Web Soil Survey were developed specifically for biochar but may be used as a guide for compost applications.

Once the concern is identified, then identify carbon amendment sources available within economic distance. Once those sources are identified, compare the carbon product tests with soil tests to ensure no potential issues with pH or nutrients. There is no reason to apply acidic amendments to acidic soils as that will create more resource concerns.

When a carbon product test results show nitrogen, phosphorus, or potassium, CPS Nutrient Management (Code 590) will apply. This includes risk assessments for nitrogen and phosphorus and a nutrient budget for all nutrient sources applied to the field. This may limit the amount of an amendment based on nutrient availability which can be applied.

Application Rates

Rates are recommended to be between 4 and 12 cubic yards per acre for any soil carbon amendment. Lower rates do not always address the carbon and organic matter concerns. Higher rates are typically not economical to apply unless in specialty crops.

Rates above 4 cubic yards per acre often tie up nutrients (biochar) or over apply nutrients (compost) which cause other concerns for the cash crop and soils. Similar to lime applications, a rate below 4 cubic yards per acre is not considered economical to justify the application costs. Exceptions will be reviewed with Ecological Sciences staff in the Missouri NRCS state office.

Compost Rate

Compost rate will be determined by the source utilized and the analysis. When a predominantly manure source will be utilized, the rate will be based on CPS 590 Nutrient Management. If a plant or treated animal by-product compost is utilized with no significant nutrient amounts being applied, then the 4 to 12 cubic yards per acre range would be used to establish the rate.

Biochar Rate

The rate that biochar will be applied depends on the resource concern being addressed. The specific rate for each resource concern will be:

- Improve or maintain soil organic matter - apply 12 cubic yards per acre maximum.
- Sequester carbon and enhance soil carbon stocks - apply 12 cubic yards per acre maximum.
- Improve soil aggregate stability - apply 12 cubic yards per acre maximum.
- Improve habitat for soil organisms - apply 4 cubic yards per acre.

Currently, suppliers of carbon amendments are limited. Trucking from out of state may not be economically feasible. When a producer finds a supplier with a product that will work for their specific site, the producer will need to verify that the supplier can meet the volume and quality of the product needed. Suppliers will need time to generate and produce the quantity of soil carbon amendments needed.

Application Methods

Amendments can be broadcast, injected, or trench applied. Broadcasting is done with traditional manure spreading equipment. While it is efficient and covers land quickly, the product is susceptible to movement off-site due to wind and water. When site conditions exist that could allow products to move off-site, products should be incorporated.

Some products can be injected through drills or injection applicators. This allows more precise application with less environmental movement. However, these methods require more time, expense, and may be limited on the volume that can be applied.

Amendments to perennial crops or trees may be applied in a specific orientation or row arrangement such as in trenches, berms, or specific areas adjacent to the rows. This allows the carbon to be located in the root zone and amendments to be applied in travel lanes and non-production areas.

References

Standardized Product Definition and Product Testing Guidelines for Biochar that is used in Soil, version 2.1. 2015. International Biochar Initiative

Building Soils for Better Crops, SARE

Biomass Pyrolysis Research, USDA – ARS.