Summary

Effects of Re-Usable Organic Materials on Transformation of Soil Organic Matter to Improve Selected Soil Properties and Functions

The application of organic amendments to soil can increase soil organic matter (SOM) and ameliorate soil physicochemical and biological properties and functions, which can be beneficial in both environmental and agricultural contexts. Consequently, due to their excellent chemical and surface characteristics, locally-sourced, reusable organic materials such as biochar and brown coal waste (BCW) are gradually gaining attention and viewed as alternative soil amendments to conventional organic materials including farmyard manure (FYM) and compost. The purpose of this thesis was to assess the effects of biochar (BIO) and BCW on soil properties (pH, cation exchange capacity (CEC), specific surface area (SSA), and C content) and functions (heavy metal (HM) remediation, humic acid (HA) transformation, nutrient cycling and crop productivity) using FYM as a comparative amendment.

Based on this, a three-year agronomic field trial at the Experimental Station of the Agricultural Institute of prof. Marian Górski in Skierniewice, Poland (ESAIMGS) was established to assess effects of organic amendments on soil properties, nutrient cycling and crop productivity. Additionally, a laboratory incubation experiment (using soil from the site of the field trial) to assess the effects of organic amendments on the bioavailability of HMs in soil. Together with samples from ESAIMGS, additional soil samples were sourced from external trials at Traismauer, Austria and Bad-Lauchstadt, Germany to examine changes in the structure of HAs in relation to SOM transformation and soil functionality after the addition of organic amendments.

Physicochemical characterisation highlighted the suitability of both BIO and BCW for soil amendments due to their high C contents, CEC and SSA; considerable nutrient contents; and low HM contents. Consequently, increasing the application of these organic amendments translated into the enhancement of soil pH, CEC and SSA at laboratory scale over the short term (9 weeks). However, at field scale over the long term (1-3 years), changes in the former two properties were found to be non-significant, indicating, in part, a potentially fading effect of organic amendment with time in addition to the lower amendment rates used in the field studies. Despite the high C contents of BIO and BCW, there were limited changes in soil C contents and thus, non-significant improvement in soil C sequestration and mineralisation potential from both amendments as well as the FYM. The effect on the formation of HAs and their structural differentiation were mainly influenced by the field age SOM (aside from the site of the trial, which introduced different pedoclimatic factors) followed by amendment frequency and the level of humified aromatic organic matter (OM) in the amendment. Thus, the HAs in the FYM-amended soil from the long-term trial (115 year) which was amended every two years along with the BIO-amended samples from the short-term trial (1.5 years), were found to have higher aromatic compounds with increased structural complexity when compared with corresponding treatments. The enhanced structural complexity can improve soil properties (e.g., pH and CEC) and reactivity for functions, such as contaminant immobilisation and nutrient cycling, which can promote crop productivity. The HM sorption mechanisms, efficacies and specificity varied based on the amendment material and application rates as well as the type of HM and level of contamination (i.e., concentration of HMs spiked in soil). BIO was found to be more effective when applied at 5% *w/w* in soil with the highest level of HM contamination (3 Cd, 500 Pb, 700 Zn) and accounted for respective maximum reductions of

25.5%, 17.4% and 11.8% in soil bioavailability of the HMs. BCW and FYM on the other hand, were more effective at 10% *w/w* in the low contaminated soil (1 Cd, 70 Pb, 100 Zn), accounting for respective maximum reductions of 69.9%, 64.3% and 17.7% and then 50.2%, 34.2% and 14.9% in soil bioavailability of the HMs. While all three organic amendments immobilised HMs by complex formation and ion exchange, binding by BIO additionally included specific adsorption by covalent bonding. The amendments increased the mean nutrient uptake by crops, which was highest in the FYM, followed by the BCW and then BIO treatments, all of which generally increased with NPK addition. Combining all crops from the three seasons, the resultant mean yield increases from the organic amendments only were in the order: BCW (33.5%) > FYM (32.7%) > BIO (21.8%) without NPK. These increased with NPK addition in the order: FYM (71.7%) > BCW (60.1%) > BIO (48.2%). This highlighted the short-term benefits of the high contents of labile and easily mineralisable OM in amendments, which are considerably higher in FYM, while also highlighting an implicit slow release of the yield-limiting nutrients (N and P) in BIO, with no additional benefits from the complex aromatic structure of HAs in soil amended by the latter.

Generally, due to their high C contents and excellent surface characteristics, BIO and BCW were shown to be more suitable for soil conditioning which translated into high HM sorption capacities, especially the latter material. On the other hand, their low labile OM and nutrient contents somewhat limited nutrient uptake by crops when compared with FYM, with BIO in particular exhibiting negative interactive effects with mineral NPK fertiliser, thus limiting crop yield increases relative to the other treatments. The study demonstrated the suitability of BIO and BCW for restoring or remediating marginal and contaminated soil while also highlighting their potential for improvement of agronomic soil.

Keywords: Organic amendment, soil organic matter, soil functionality, humic acids, nutrient uptake, heavy metal bioavailability