**Introduction Draft for Feedback (“Treating soils like dirt: the failure of the European Union to combat soil degradation in Europe”)**

Paragraph 1 – What is the problem? (These subtitles wont be included in the actual introduction)

Soil degradation is arguably the greatest limiting factor of global productivity growth (Bindraban et al., 2012). Degradation of soil refers to the loss of the present and/or future ability of the soil to provide functions and services due to a decline in soil quality (Lal, 2015). This can be a direct result of natural processes, such as water or wind erosion (Bindraban et al., 2012). However, it most commonly arises from anthropogenic activity caused by socioeconomic pressures and population growth. Examples include deforestation, intensive agricultural practices, and urbanisation. These developments disrupt the natural fortification of a soil and its vegetative cover against climatic hostility (Oldeman, 1992). This is partly due to most human activities being depletive of the natural environment (Abrol et al., 1990). Four types of soil degradation have previously been defined: (i) physical; (ii) chemical; (iii) biological; and (iv) ecological. Soil physical degradation refers to a loss of structural attributes in the soil, which exacerbates crusting, compaction and hardsetting, soil erosion and sedimentation, soil temperature fluctuations, and laterisation. Soil chemical degradation is identified by acidification and salinisation, nutrient depletion, excessive leaching of cations, and contamination by industrial waste leading to a toxicity imbalance that is detrimental to plant growth. Soil biological degradation is characterised by a decline in soil organic carbon (SOC), activity, density, and diversity of soil fauna, and the capacity for soil C sink retention. Consequently, biological degradation can lead to soils being a net output of greenhouse gas emissions (GHG), such as carbon dioxide (CO2) and methane (CH4). Ecological degradation is a consequence of all three soil degradation types and presents itself in the impairment of ecosystem processes, including nutrient and hydrological cycling, and a reduction in net biome productivity.

Paragraph 2 – Why is this problem happening?

The causes of soil degradation are multifaceted. Agriculture is one of the leading causes of stress to the environment (Seybold et al., 1999), and its effects can be seen long after the period of cultivation has ended. Agriculture refers to any crop-plant production system, and has huge ramifications for soils and surrounding ecosystems (McLauchlan, 2006). Soil can be categorised as “resilient” or “resistant” based on how it responds to agricultural perturbation (Seybold et al., 1999). A soil that is particularly vulnerable to change under agricultural management practice but rapidly returns to its original state would be defined as “resilient”. In comparison, a “resistant” soil can withstand greater levels of management intensity without changing, but once changed may lose the ability to return to its initial condition. Biomass amendments, tillage, fertilisation, and altered hydrology are specific agricultural management practices that have the potential to drastically change the quality of the soil. The elimination of naturally competing plant species and introduction of annual crop plants significantly alters plant biomass. Annual harvest diminishes organic carbon returns to the soil (Imhoff et al., 2004); in an agricultural system SOC is a linear function of carbon loads from crop residues (McLauchlan, 2006). Inversion tillage creates belowground disturbance through the pulverisation of the topsoil that increases SOC decomposition rates (Reicosky et al., 1997; Collins et al., 2000; Six et al., 2000) and enables physical soil erosion due to the lack of vegetation cover. Research shows that after 100 years of maize cultivation, agricultural land contains less than half the amount of topsoil in comparison with perennial grasslands (Gantzer et al., 1991). The full extent of soil degradation caused by inversion tillage can only be realised decades after its use: subsoil begins to appear at the surface, tillage-related landforms such as tillage banks form, and tillage translocation (the movement of the cultivation layer) takes place (Van Oost et al., 2006). Nutrient inputs through fertilisation can cause changes to the microbiome, leading to shifts in soil characteristics (Lin et al., 2019), and subsequently, whole ecosystems (Wang et al., 2011). Irrigation exacerbates siltation, salinisation and sodicity, and can cause an anaerobic shift in the soil, leading to loss of soil hydroecological functioning (Assouline et al., 2015) and irreversible soil damage (Yin et al., 2021). Additional factors influencing soil degradation include continuous cropping/grazing and the use of heavy machinery. This is due to grazing interrupting the natural cycle of returning mineral-rich, dead plant matter to the soil, and machinery compacting the soil, which in turn prevents water infiltration and accelerates erosion. Soil degradation processes such as these call conventional management practices into question.

Paragraph 3 – Why should we care about this problem?

Three quarters of terrestrial ecosystems are impacted by soil degradation, with no intervention this number could rise to 90% by 2050 (Pereira et al., 2019). Soil degradation affects more than half of the global agricultural systems, adding a huge strain to approximately 54% of global ecosystem services (Nkonya et al., 2016). More recently, there has been significant interest from scientific researchers regarding the increasing interactions of the pedosphere, biosphere, and atmosphere as a result of soil degradation. The pedosphere is the second largest carbon reservoir on the planet (Stolte et al., 2016). An estimated 2400 Pg of soil organic carbon (SOC) is locked in the upper 2 metres of the soil (Kirschbaum, 2000). However, soil degradation processes such as soil erosion have the potential of unlocking this soil organic carbon and releasing it into the atmosphere. Currently, there is an active debate in the scientific community regarding whether soil degradation and associated ecosystem changes translates into a net C sink or source for atmospheric CO2. It is widely known that soil degradation has huge influence over the global carbon budget. Berhe (2007) estimated that over time the volume of CO2 unlocked from the soil and released into the atmosphere would be equal to three quarters of all fossil fuel carbon emissions. Within the last two centuries, 200 Pg C has entered the atmosphere as a direct result of land conversion and soil degradation (DeFries et al., 1999). The work of Lal (Lal 1995, 2001, 2003a, 2003b, 2003c, 2004) lends huge support to this debate, having found that soil degradation process, such as soil erosion, are a source term as opposed to sink, in the global carbon budget. They predict that annually 1.14Pg C is being released into the atmosphere from the soil due to aggregate breakdown. There is significant support for these finding in the literature (Schlesinger et al., 1995; Starr et al., 2000). A n evidence-supported conclusion of this debate would have huge implications for the future of soil science, ecology and environmental policy.

Soil degradation also has important economical consequences. At the going rate, the cost of no intervention is significantly higher than the cost of intervention (Mirzabaev et al., 2015). Estimations of the global revenue lost as a result of soil degradation processes range from 300 billion US dollars (Nkonya et al., 2016; Pancheco et al., 2018) to 6.3 trillion (Sutton et al., 2016), on account of impaired ecosystem function. In Europe, it is thought that the European Union suffers losses of 1.25 billion Euros annually, due to a reduction in agricultural productivity, as a result of 12 million ha of European soils being degraded (Panagos et al., 2018). Similarly, the United Kingdom bears the brunt of a heavy 1.4 billion pound deficit as a consequence of the aforementioned soil degradation (Graves et al., 2015).

Paragraph 4 – How can we fix this problem?

Land degradation must not only be reduced, but reversed to ensure long-term productivity. As intensive land management practices are largely responsible for soil degradation, it would be logical to conclude the implementation of less intensive practices is key to rehabilitating degraded land. Conservation Agriculture (CA) has the ability to reduce soil degradation and increase soil productivity (Pereira et al., 2019). Conservation Agriculture, also known as no-till farming, is based on three principles: i) no-till seed drilling; ii) continuous vegetation cover with organic mulch e.g. crop residue, green manure, cover crops; and iii) maintaining plant diversity by creating polycultures of crops. In contrast to conventional agricultural practices, CA wields the natural diversity of the ecosystem as a tool to propagate soil health and productive capacity (FAO, 2011). CA has the ability to encourage infiltration and storage of water in the soil, and indirectly improve interactions in the rhizosphere between plant roots and soil microbes, as well as the uptake of nutrients (Kassam et al., 2014). This builds resilience in the soil to environmental stressors. There is ample documentation surrounding the benefits of CA practices in long term studies, including: positive responses of soil biota to the removal of mineral fertilisers and pesticides (Henneron et al., 2015), increased soil fertility as a result of crop diversification (DiFalco et al., 2017), and boosted soil productivity under wide crop rotations and cover crops (Ranaivoson et al., 2017; Garcia-Gonzalez et al., 2018). There is enough evidence to imply that the implementation of CA, in conjunction with other defensive management practices to combat erosion and enhance SOC, has the potential to conserve our soils (Lal et al., 2013). For this reason, CA is at the forefront of approaches proposed in the FAO sustainable agricultural intensification strategy (FAO, 2011). Additionally, among the 17 sustainable development goals (SDG’s) proposed by the United Nations (UN) in their agenda for 2030, there is mention of achieving Land Degradation Neutrality (LDN), which cannot be achieved without CA (Kust et al., 2017; Pereira et al., 2019) as agriculture is a primary cause of degradation.

*Notes to include in this paragraph:*

*Soil degradation is detrimental to livelihoods of poor farmers and results from agricultural practices that deplete the organic matter and nutrient content of the soil. A wide range of techniques can be applied, such as reduced tillage, residue management, mulching, crop rotation, crop mixtures, cover crops, manure application, agroforestry with soil improvement through nitrogen-fixing trees, terrace building, pitting systems, water harvesting techniques, drainage ditches, small dams in valley floors, drip irrigation, and so on to conserve soil and water, and to prevent soil degradation and increase crop yields. Interventions should be specifically targeted to farming systems as well. Interventions that aim at increasing productivity and the nutrient use efficiency at farm level, should take the predominant farm-type and nutrient management strategy into account to target the main loss pathways. Proper management of crop residues and integration of crop and livestock farming along with N fixing crops, and SLM techniques like stone rows and grass strips are necessary to ensure nutrient cycling, reduce erosion and gradually increase soil organic matter content. Evergreen agriculture or ‘fertiliser trees’, that is, the intercropping of particular tree species into annual food crop systems to sustain a green cover on the soil throughout the year, can bolsters nutrient supply through nitrogen fixation and nutrient cycling. It also generates greater quantities of organic matter at the soil surface thereby improving soil* *structure and water infiltration, at rates of 2-4 t C ha-1 compares to 0.2-0.4 t C ha-1 under conventional farming systems. Terracing and straw mulching have been widely adopted and found effective in increasing soil water storage (e.g. by an additional 26mm over 1m soil depth under straw mulching) and yield (e.g. 15% higher spring wheat yield under mulching), while reducing erosion.*

*Conservation agriculture (CA) is often claimed to offer great potential to address land degradation and improve livelihood; including improvement in soil fertility, reduction in soil erosion, carbon accumulation, savings in time and energy (fuel), and increased biodiversity obtained from reduced or eliminated tillage, soil cover and crop rotation. Yet, differences in both agro-ecological as well as socio-economic conditions show that CA is not generally applicable to combat degradation and enhance crop production and needs to be tailored to specific conditions. The success of CA is challenged in environments where soils are inherently poor; have physically hardening properties, have low chemical nutrient and C levels, and have very little biological soil fauna activity. More intensive weed control also demands more labour for which there is neither interest nor incentive as yields may drop after conversion to CA. Poor access to inputs jeopardise the needed increased dependency on herbicides, while continuous cover crop is not possible because of climate, and crop rotation is limited by market mechanisms.*

Paragraph 5 – What is my specific project about?

Haven’t written this paragraph yet. Planning on justifying why I chose soil microbial diversity and abundance as a proxy for soil health/degradation.

*Soil microbial abundance and activity parameters are common metrices recommended by the US Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) as soil health indicators particular to soil microbial properties.*

*Objectives of this project are:*

*To assess if there are differences in the levels of soil degradation (using soil microbial diversity and abundance as a proxy) between levels of intensively managed agricultural land.*

*To ascertain if the EU soil health goals for 2030 by switching to less intensively managed agricultural land are achievable based on these findings.*