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LANDSCAPE PLANNING MASTER'S DEGREE

BIOCHAR EFFECTS ON SOIL RESTORATION IN VINEYARDS

RESTORATION OF SOIL QUALITY WITH BIOCHAR EXPERIMENT IN VINEYARD AND FOREST'S SOIL

DIPLOMA THESIS

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DIPLOMA THESIS ASSIGNMENT

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Landscape Engineering
Landscape Planning

Thesis title

Biochar effects on soil restoration in vineyards

Objectives of thesis

The aim of my thesis is to:
- verify biochar effects on soil´s quality improvement on soil restoration process;
- analyse relation between soil´s quality and vegetation cover for landscape restoration purposes;
-verify biochar application as a strategy to restore Cu-contamination on vineyards soils;
- set recommendation for land reclamation planning proposal for the study location.

Methodology

My study will include laboratory experiments and regarding physical, chemical and biological components in soil with biochar; data process and analysis; statistical treatment of data; field work; vegetation cover estimation.

The vineyards in my study are located in Portugal, in the Bairrada region (close to Aveiro).

The proposed extent of the thesis

40-60

Keywords

land reclamation, soil quality, vineyards

Recommended information sources

Ameloot, N., Graber, E. R., Verheijen, F. G., & De Neve, S. (2013). Interactions between biochar stability and soil organisms: review and research needs. European Journal of Soil Science, 64(4), 379-390.

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Wilson, A. M. (2016). Effects of Biochar, Fertilizer and Shelter Treatments on the Vegetation Development Following Coal Mine Reclamation.

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Dean

Prague on 19. 03. 2022

AUTHOR'S DECLARATION

I hereby declare that I have independently completed this diploma thesis, titled "Biochar effects on soil restoration in vineyards" and I have cited all the information sources that I used in the thesis within the resources section.

I am aware that my diploma thesis is subject to Act No. 121/2000 Coll., on copyright, on rights related to copyright and on the amendment of some acts, as amended by later regulations, particularly the provisions of Section 35(3) of the act on the use of the thesis.

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With my signature, I also declare that the electronic version is identical to the printed version and the data stated in the thesis has been processed about the GDPR.

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Prague, 2022 Suyan Roberta Isaka

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ABSTRACT

The use of biochar has increased worldwide in the last years due to improvements for several soil quality indicators. However, restoration potential depends on the type and amount of biochar for each specific soil and land use. This thesis aimed to investigate this restoration potential differential; we conducted an experiment where we amended two contrasting degraded soils with the same biochar. We installed a controlled and fully randomized percolation lysimeter experiment (3 replicates) with 15 lysimeters on a moderately steep slope angle, monitored for one year. In the north-central Portugal at the University of Aveiro. Two types of soil were collected, a low organic matter vineyard soil and a high organic matter forest soil. The viniculture soil was from the district of Aveiro, and the forest one from the district of Coimbra. Biochar was applied at 4% (w/w) for both soils, and an additional treatment at 2% for the forest soil only. Selected soil quality indicators were: soil organic matter, mean weight diameter, aggregate stability, bulk density, pH, electrical conductivity, and moisture content. The present study comprises four data collections in different seasons along the year, enabling to compare the development of the biochar effects on different types of soil and its short- and medium-term behavior. Biochar influence is closely related to soil texture, which was noticed on the different results from each soil. While vineyard soil became less dense, forest soil had no significant effect. Opposite for pH experiments, in which the latter had a small change, the earliest had no changes. With so, this thesis contributes for studies concerning experimental biochar application and soil quality effects comparison. Biochar can become an option to amend degraded soils by modifying its aspects.

KEYWORDS: soil degradation, lysimeters, sustainable alternative.

ABSTRAKT

Používání biouhlu se v posledních letech celosvětově zvýšilo díky zlepšení několika ukazatelů kvality půdy. Potenciál obnovy však závisí na typu a množství biouhlu pro každou konkrétní půdu a využití půdy. Cílem této práce bylo prozkoumat tento rozdíl potenciálu obnovy; provedli jsme experiment, kde jsme upravili dvě kontrastní degradované půdy stejným biouhlem. Instalovali jsme řízený a plně randomizovaný experiment s perkolačním lysimetrem (3 repliky) s 15 lysimetry na mírně strmém úhlu sklonu, monitorovaný po dobu jednoho roku. Na severu centrálního Portugalska na univerzitě v Aveiro. Byly shromážděny dva typy půdy, půda vinic s nízkým obsahem organické hmoty a lesní půda s vysokým obsahem organické hmoty. Vinařská půda pocházela z okresu Aveiro a lesní z okresu Coimbra. Biouhel byl aplikován při 4 % (m/m) pro obě půdy a další ošetření při 2 % pouze pro lesní půdu. Vybrané ukazatele kvality půdy byly: organická hmota půdy, průměrný hmotnostní průměr, stabilita agregátu, objemová hustota, pH, elektrická vodivost a obsah vlhkosti. Tato studie zahrnuje čtyři sběry dat v různých ročních obdobích, což umožňuje porovnat vývoj účinků biouhlu na různé typy půdy a jeho krátkodobé a střednědobé chování. Vliv biouhlu úzce souvisí se strukturou půdy, která byla zaznamenána na různých výsledcích z každé půdy. Zatímco půda vinic se stala méně hustou, lesní půda neměla žádný významný účinek. Naproti experimentům s pH, ve kterých došlo k malé změně, první z nich neměl žádné změny. Tímto způsobem tato práce přispívá ke studiím týkajícím se experimentální aplikace biouhlu a porovnání účinků kvality půdy. Biouhel se může stát možností, jak změnit degradovanou půdu úpravou jeho aspektů.

KLÍČOVÁ SLOVA: degradace půdy, lyzimetry, udržitelná alternativa.

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1. Introduction

Soil is a natural resource that takes relatively long to form. Merely 1 to 2 cm in 100 years and may take more than hundred years to recover by itself; meaning it can be understood as non-renewable resource (State of the soil in Europe, 2012).

Considering this, the Soil Thematic Strategy of the European Commission (COM (2012) 46) developed a system of soil treats in Europe, consisting of accelerated soil erosion; soil compaction, desertification, and loss of soil biodiversity, among others (Stolte *et al.* 2016). For example, the use of chemicals to maximize the agriculture is very usual since decades, which once was a great invention that allowed our world to increase food productivity and satisfy most of the worldwide population's needs. Unfortunately, the use of chemicals encroached natural resources such as water contamination and soil degradation (Verheijen *et al.* 2019). Overall, land degradation is mainly caused by overuse of the land for food and wood production. Hence, overuse of the soil without a sustainable management (Olsson *et al.* 2009). Thus, new techniques started to be developed accordingly to reduce land degradation, such as nature-based solution. Biochar has become an agricultural/environmental management tool enabling to reduce previous chemical contaminations and/or improving soil quality and agricultural productivity. (Lehmann, J., & Joseph, S, 2015 ; Yavari *et al.* 2015 ; Trakal *et al.* 2011).

This thesis aims to contribute to soil restoration research, by comparing the effect of biochar amendment on soil quality for two contrasting degraded soils, in a one-year percolation lysimeters study. These devices allow soil-water relationship measurements. Percolation lysimeters permit measurement of the percolating water volume (Howell, 2005) and the soil water chemistry. For this research, experiments were conducted on soils originating from vineyard and forest areas, located in the north-central region of the country.

The experiment was conducted on two contrasting soils – in bulk density, soil organic matter quantity/quality – in the Lysimeter Park of the University of Aveiro, and therefore, under similar conditions, such as rainfall and temperature, to contribute to our understanding of how the same biochar may have varying effects in different soils. It is expected that the results of this study will be useful for other studies involving biochar and soil experiments to investigate soil's chemical, physical and biological conditions, and thereby, contribute to developing the use of biochar potential for soil restoration.

2. Aims

The thesis hypothesis was: biochar application to degraded vineyard and forest soil increases specific and overall soil quality.

The following objectives were

- To determine the effect of biochar amendment on soil structure indicators.
- To determine the effect of biochar amendment on soil chemistry indicators.
- To compare specific and overall soil quality for the two contrasting soil types.

3. Literature review

After the mid-20th century with the Green Revolution in agriculture, the food production worldwide increased and so, the independence from nature's cycles. However, soil is the finite resource in need to produce any food itself. As the years go by, population increase as well human needs, aside nourishment.

The expansion of urbanisation and agricultural fields over natural ecosystems and soil exploitation required implicates on escalation of carbon (C) emissions as result of soil degradation and desertification, along with water drainage, biomass burning, mineralization of soil organic matter (Olsson *et al* 2009; Lal, 2010). With no human lifetime for natural restoration, many solutions were created aiming to improve its capacity for productivity.

For over centuries, in the Amazon basin biochar had been used called as "terra preta", ameliorating soil's quality on nutrients and properties, being well known as very fertile. Nowadays, biochar has proved in many studies to be more efficient than biogenic soil organic matter for certain types of soil (Novak *et al*. 2009).

Biochar can be created through pyrolysis of C-based biomass, which means it is an organic material; and according to Verheijen *et al.* (2009) it can be defined as "charcoal for application to soils".

Its usage purpose is to increase soil productivity meanwhile contributing to environment's improvement. And both aspects can be observed through biochar behavior or influence on carbon sequestration (Verheijen *et al* 2009, Lal 2010), fertility increasement, soil structure and reduction of soil loss (Verheijen *et al* 2009), pesticides sorption (Yavari *et al.* 2015).

3.1. Soil degradation

According to the report State of soil in Europe (2010), soil consists in the out-layer of the planet, formed by water, air, organic matter and mostly material from previous rocks, minerals. It is not only the "floor-base" for all landscapes composed by all living beings, but the provider resource required to sustain life. And that is the reason why it is high value.

Therefore, soil degradation means reduction in soil quality, as in its productivity (economic value) and supply ecosystems services (ES) (Lal, 2010). With so, there were listed mankind soil threats in Europe, embracing erosion by water and wind; reduction of organic matter, biodiversity, soil function; increase of desertification, salinization, compaction, contamination, sealing; and higher occurrence of flooding and landslides events (Stolte *et al* 2016). All leading to land degradation, defined as decline of biological and ecological excellence, productivity or integrity, including forestry land; in such wise, processes which impact on soil (Olsson *et al.* 2009).

According to the Food and Agriculture Organization of United Nations (FAO, 1992), there were identified twelve types of soils degradation by the Global Assessment of Human-induced Soil Degradation (GLASOD) around the world. The considered reasons were changes in the land use, suppressing and replacing the natural covers for agricultural and industrial activities. (FAO, 1992).

Ultimately, degradation refers to induction of natural processes by humankind activities causing negative effects on soil, in any aspect. In the following, the three soil conditions were discussed.

3.1.1. Structural

Soil texture, structure development and organic matter content are some of the soil attributes that influence on soil's characteristics, such as water infiltration rate. Altogether, these components influence on soil erodibility. That way, erosion happens on soil exposed (uncovered) to the actions of water or wind (Pimentel and Burgess, 2013). So far, erosion is a natural process that occurs to the soil. However, when it is intensified or induced by mankind activities, it becomes a soil degradation type.

With so, soil structure is degraded when its texture become finer, meaning loss of its natural texture. The structure gets loose and breaks more easily, so there is a reduction on pores for aeration or for water to infiltrate. Because of it, there is a reduction also on space for water infiltration both for roots to grown (and fixate) into. The roots that manage to surpass the conditions and do spread itself, face lack of water and air, less nutrients, and offer less to e. g. nitrogen (N), carbon (C), phosphorus (P) cycles. All things considered also diminish the organic matter.

In this matter, soil texture can be modified when submitted to compaction actions. With the pressure of weight over soil surface, it crushes the arrangements and forms (Jones *et al* 2012, p. 18). Likewise, soil erosion by wind and water energy contributes to break the structure into particles and, therefore, transport of sediments causing soil loss and depth reduction as well (Stolte *et al*; Borelli *et al,* 2016).

Because of the erosive process summed with land topography and vegetative cover (Pimentel and Burgess, 2013), the natural events as flooding and landslides have become more susceptible to occur (Stolte *et al.*; Keizer *et al.* 2016). The occupation of river margins along with the impermeabilization of the surfaces create inappropriate locations for human occupation - which is a social privilege, another economic and social issue that impacts on environment (Davis, 2006; Stolte *et al*; Keizer *et al.,* 2016). Same with occupation of hills and valleys, specially under specific climate conditions e. g. tropical. For one or the other, natural conditions unfortunately come to impact on human's lives due to an environment overlap matter, consequence of land use change.

3.1.2. Chemical

Environmental contamination happens when there are any agent(s) in a sufficient concentration to produce harm to environment's well-being, in one or all aspects. Also, agent refers to any organic or inorganic contaminants (Mirsal, 2008, as cited in Stolte *et al* 2016), substance(s) with possible capability to impact negativity the environment, momentaneous or permanent, becoming a pollutant. Thence, soil contamination regards the scenario when soil function loss or chemical degradation come about because of the presence of specific contaminants concentration in the soil (JCR, 2014). Aside productivity and functioning, this soil contamination or pollution interferes on biogeochemical balance, causing changes on soil properties (Stolte *et al.*; Anaya-Romero *et* al.2016).

Contaminants can be released to the environment in two different ways, point or diffused sources (Adriano, 2001, as cited in Stolte *et al* 2016). The first one refers to a pollution spot, e. g. dumping ground. The second concerns to an escalating process over time becoming a diffused contamination, e. g. pesticides application.

Hence, the soil contamination can be cause by natural sources, as volcano. However, this contamination does not bring the same results as anthropogenic ones. Soil as part of the environment can be compromised directly or indirectly. Soil behaves as a sponge, sink or

deposit, receiving contaminant agents from various types of pollution. (Alloway, 2013, as cited in Stolte *et al*, Anaya-Romerto *et al.*2016).

It also increases other soil threats such as biodiversity, soil erosion by water and wind. With main aftereffects including loss of biomass production; decline on carbon pool performance and filtering, storing, and altering water, substances and nutrients; among others.

Soil salinization refers to the irregular concentration of salts (water-soluble) or sodium in all or any soil parts, such as upward part (solum), horizons A and B, even in the layer of loose unconsolidated rock material (soil regolith) (Rengasamy, 2006, as cited in Stolte *et al.*;Tsanis *et al*2016). Because of it, soil aggregates are destructed and so, its structure (Li *et al* 2012, as cited in Stolte *et al.*;Tsanis *et al* 2016, p.112).

Moreover, salinization as a soil degradation is a consequence of human interventions, but exist also natural saline (Jones *et al* 2012:p 21) – which is influenced by the climate conditions and so, also susceptible to impacts from human activities (Stolte *et al.*/Tsanis *et al* 2016).

Salinization happens when water washes away all the soil contents and leave the salts behind, increasing its concentration on the soil. This washout is an action-reaction chain, most likely to occur when the surface is exposed or with a weak coverage, sensitive to erosive processes. Therefore, the removal of finer particles and so the topsoil by wind or water actions (induced and natural) drives into sheet, rill and gully erosions. Silt and clay are mostly transported away, and fine sand (and bigger particles) becomes most of the soil land. The combination of residual clay particles with this fine sand leads to soil sealing and the top becomes harder. Infiltration rate declines. Bulk density increases. Water storage reduces. Loss of biodiversity habitat, the salt content also impacts on animals and plants living conditions (Stolte *et al.*/Tsanis *et al* 2016).

Since the salt concentration can reach up to the level of interfering on soil structure, therefore on environment conditions and crops productivity once it extends to metabolisms of soil organisms – extinguishing the vegetation and so fertility. It impacts other resources as well, e. g. the water usage by increasing its salt content. In the end, the degraded land becomes unusable (Stolte *et al* 2016, p. 104).

As soil contamination, salinization has been a widespread issue across the world (FAO, 2011), and in Europe it had been pointed mostly in the Mediterranean countries. This threat

intrinsically linked with desertification causes most importantly the destruction of soil structure aggregates and nutrients loss.

Soil acidification caused by leaching with loss of base cations and increase of aluminium (Al) and iron (Fe) cations concentration in the soil (Jones *et al* 2012:22). Plus, its acid neutralization ability declines, so it becomes. Acidification is also a natural process that happens with the soil after volcanic activity, deposition of certain leaves or tree sap etc., and the soil has a natural geochemical reaction process for neutralizing such. But as mentioned before, the degradation refers to anthropogenic related activities potentialize it. Examples of it is the emission of gases into the atmosphere resulting in acid rain/precipitation (SO2, NOx, NH3, NO3 which can form acids), from e. g. combustion of fossil fuel and agrochemicals; combined with induced erosion and so impacting on soil conditions (Jones *et al* 2012).

Well environmentally interconnected, it impacts on the whole water cycle: the air pollution from rural and urban areas leading to soil and so water, in a continuous chain to the rivers and ocean, and from it back to atmosphere. Reaching out all the sides of environment, impacting since microorganisms until landscapes (Jones *et al* 2012).

3.1.3. Biological

Soil biodiversity refers to all the life inhabiting the soil. Constructing an interdependent and interrelated network of life, big provider of ecosystem services. This biodiversity helps soil formation, bringing to the soil nutrients from organic matter and influencing on soil's structure and ongoings, as its capacity to infiltrate and retain water (Lavelle and Spain, 2001, as cited in Jones *et al* 2012), its porosity and density, "details" that later define landscapes and biogeography. As said before, all types of degradation impact on soil biota. So does the lack or loss of biodiversity, impacting on soil quality.

One example is the soil sealing, which happens when covering the soil with impermeable materials (Jones *et al* 2012). Clearly, isolating the soil from any type of life, block the surface, unable to filtrate water, perform biogeochemical cycles, meanwhile increase hot island effect on urban areas, and overall, can only serve as base for human activities (European Commission, 2013).

Furthermore, the degradation types can be combined and cause other, such as desertification, meaning biological loss joined with structure and chemical properties of the soil. From the erosive process by wind and water causing structure loss, to the transport of fine particles, allowing only sparse uneven vegetation growth and unfortunately supporting the erosion intensification forming small channels to gullies. Washing the nutrients away, increasing soil salinization, reduction of vegetation growth (fertility) and so vegetation cover, all interlinked in a cause-effect cycle. Finally, the resource loses its function and no longer can provide soil-based-services. Loses its value economically due to its subsequent productivity decline and no longer consist in a good natural (nor artificial) habitat for animals or plants (Stolte *et al.*/Kirkby *et al* 2016). Sensitive to those risks and types of degradation, soil functions become threaten, along with ecosystems services.

3.2. Links to threats to soil & ecosystem services

Ecosystem services is a concept which link "human well-being" with ecosystems, conjoining society (Stolte *et al.*/ Schwilch *et al* 2016), economy and ecology aiming sustainable management. Hence ES has been always measured by its value to humanity (Braat and de Groot, 2012).

Soil functions and ecosystem services are connected, as a chain. Soil degradation compromise soil function, which is induced by soil threats and afterwards, likely to disturb ES in general. There are more ES threats, but in this thesis the focus' on refereeing to soil-related-services, as for Stolte *et al.*/ Schwilch *et al*. (2016).

With so, its functions comprehend human's environment and physical basis for their activities; consist in result of geological and archaeological development, as a patrimony; fount of raw materials; source producer (biomass) for nourishment and wood; comprise habitats for all living organisms meanwhile providing conditions for biodiversity; and yet, perform/behave as storage, filter, transformer and sinker of carbon, nutrients, water and other substances (Stolte *et al.*/ Schwilch *et al* 2016:156). Which are, as mentioned previously, functions threatened by human activities which tend to reinforce soil degradation and so, its capacity to provide services.

Again, soil's conditions impact not only agriculture production but all human occupied land. Natural hazards as flooding and landslides were recognized as threats because of population widespread, over either rural or urban areas. Though both are considered "local soil threat", as

result of occurrence in more places and more often (since the occupied human territory has expanded), the natural events became threats to the society (Stolte *et al.*/ Schwilch *et al* 2016).

3.3. Evidence of biochar mechanisms and effects

The impacts of biochar amendment on soils are related to the biomass feedstock and pyrolysis process, biochar particle size and application strategy, influenced by weather conditions, application period and soil type, as well as land use and management.

Biochar particle size impact on soil structure. The particles can be transported away, fractioned into smaller sizes, or oxidised when submitted to eventual conditions (such as fire); and these changes reflect on biochar's operation on soil. Research over the last 10-15 years has provided evidence of various biochar mechanisms and specific outcomes of its application (Verheijen *et al.*, 2009; Joseph *et al.*, 2021).

Some studies have shown biochar use could culminate into adverse results, for instance rise of soils water repellency, bulk density, reduction of water infiltration and retention, consequently undermining soil biodiversity and environmental -ecosystem services loss; among other effects opposed to improvement of soil quality (Smetanová *et al*. 2012).

These situations were mostly related to situations that could change biochar's particles properties, such as: submitted to high temperature as fire events; application of biochar itself with the use of heavy machinery combined with biochar particles with lower resistance could lead to break down of its particles into smaller fractions, or even simply as time goes, allowing the "clog" of soils pores together with soil compaction (Blanco-Canqui, 2017; Verheijen *et al* 2009).

But overall, many investigations have produced evidence to affirm that: when considered biochar's mechanisms, its production procedure and best selection accordingly to its purposes, biochar can be and has proven useful on amelioration of soil structural and chemical condition (Schmidt *et al.,*2021; Blanco-Canqui, 2020; Bastos *et al*. 2020; Novak *et al.* 2009).

Biochar has low bulk density compared to soils mineral particles. Therefore, when applied to the topsoil, biochar particles bind to mineral soils particles and aggregates resulting in, comprehensively, reduction of soils BD (Blanco-Canqui, 2017; Hardie *et al.* 2014).

Blanco-Canqui (2017) and Hardie *et al.* (2014) affirmed that particle's density is closely related to soil porosity and impacts on sedimentation and deposition, surface area, physical-chemical properties directly influenced by temperature; and biochar studies outputs present it's reduced particle density through rising soil aggregation level, biding with mineral soil particles and diminishing soil as well as increasing soil aeration, besides biochar particles with high porosity itself; resulting in soil porosity (Hardie *et al.* 2014).

Soil porosity is also related to water infiltration, retention, and repellency. The simply increasing on water entrance or inner space availability does not imply water infiltration if there is high repellency, leading to only air and water entrapment without providing conditions for soil processes (Blanco-Canqui, 2017). Nevertheless, more recent studies on biochar and water in soil have revealed overall improvement on soil drainage, with infiltration and saturated hydraulic conductivity level increase; and water conservation, joined not only to with water retention but availability – both are related to soil texture (Blanco-Canqui, 2020).

Bulk density itself is related to soil compactibility, and for Soane (1990), soil organic matter level interferes on soil resilience in this matter. SOM level is proportionally related to soil elasticity, electrical charge, bonds among particles and aggregates, among others (Soane, 1990). Studies regarding biochar have presented a protective effect over organic matter, formation of macroaggregates and storage of carbon in it; also connected with soil texture (Wang *et al*2017)

Besides, it has been learnt that biochar relation with soil texture assists on soil aggregation as well. According to Ajayi and Horn (2017) experiments, it has risen medium and fine pores percentage (and water holding and aeration). Additionally, biochar-applied-soil had more elasticity, adherence, and mechanical strength.

Controversial results related to soil and biochar application suggest further investigation, as for soil moisture, water infiltration and hydraulic conductivity as examples, since different studies have pointed distinct results (Hardie *et al.* 2014).

In this way, biochar contributes to soils biological conditions, as increases nutrients retention; improvement of aggregates and macropores affects rooting and mycorrhiza fungi development; carbon and nitrogen cycles; among others englobed in soil life (Semida *et al*. 2019; Trazzi *et al.* 2018; A. E. Ajayi and R. Horn, 2017; Blanco-Canqui, 2020).

Scientific understanding of biochar effect on particle bonding and soil texture leads investigations to soil pH . Although biochar's feedstock option is plenty, the pH range discovered stays between neutral and basic, values over 6 and lower than 10 (Verheijen *et al.* 2009).

According to Liu and Zhang (2012), its application resulted in lowering oh pH in alkaline soils, possibly due to its particle oxidation over time, which could mean inhibit contribution wise to salinization process.

In the other hand, experiments done by Jones *et al*. (2012) on Eutric Cambisol soil type with usual presence of iron (Fe), in this case slightly acidic which had its pH lightly increased but enough to neutralized it. Same for Liu *et al.* (2012) analysis in Dystric Cambisol, pH did not increase greatly. However, both agree there are still missing long term experiments results for further effects discussion.

The alterations biochar is capable of in physicochemical soil properties can affect carabondioxide emissions and microbial activity, being an expressive reason by the pH changes in some cases, as in Sheng and Zhu (2018) studies in ferralsol soil. The small increase on pH was though very significant for other aspects observed and so for CO2 emission diminution in certain soil type and treatment.

Jones *et al.* (2012) revealed a small reduction of pH values along the experiment period, and the electrical conductivity values dropped significantly. Which still did not have negative effect on soils quality, and increased soil basal respiration and water content.

On the other hand, Chintala *et al.* (2013) research with acidic soil had great increase of pH and EC. The distinct types of biochar feedstock and treatments produced different outcomes regarding increasing significancy, but overall had no values reductions. The authors address such results to biochar chemical base cation concentration found.

The amount of biochar applied however did not result into expressive changed though (Ajayi and Horn, 2017). Generally, research on biochar have outcomes either on amelioration of soil properties or no change at all, but no deterioration of soil's pre-existing conditions. Yet, biochar feedstock and pyrolysis process have been played important role in biochar behavior and

should be considered as well as its application purposes and soil conditions (Hardie *et al.* 2014; Jones *et al.* 2012; A. Smetanová *et al.* 2012; O. Mašek *et al.* 2013)

Research on biochar have attributed that it can act not only on specific soil properties in small scale. It can also exercise a big role in global scale, as in mitigation for soil's degradation, gas emission, improvement on soil-plant wise quality, among others (Joseph *et al*2021)

4. Methodology

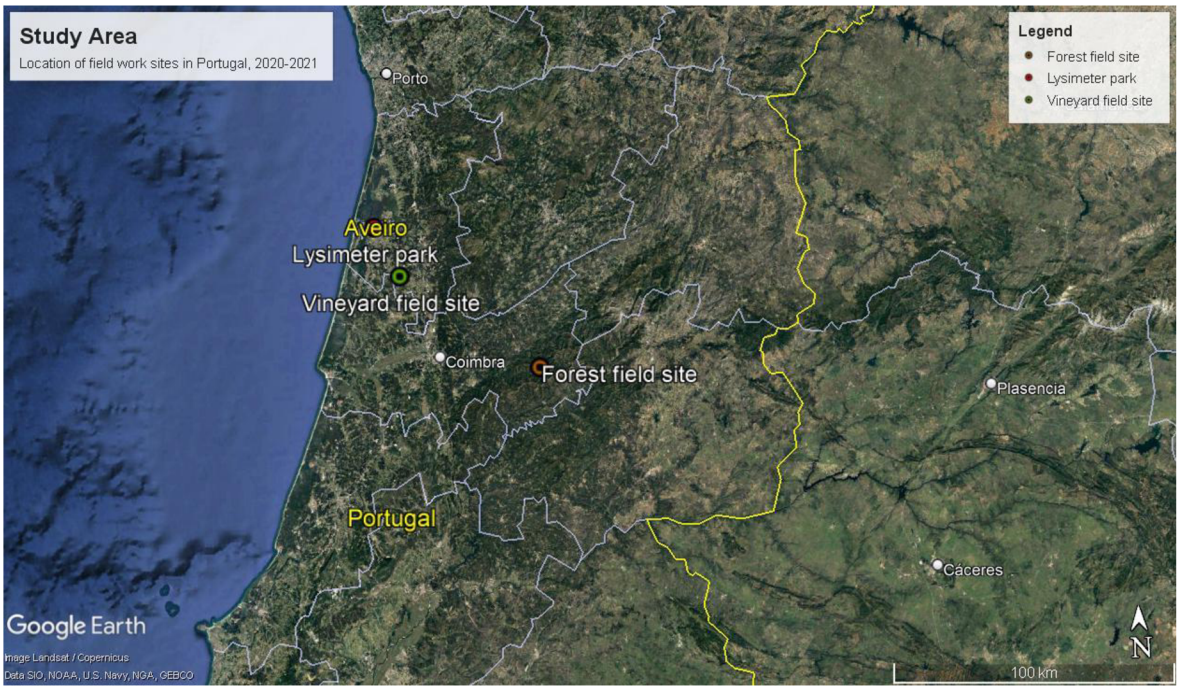
To find answers to the research objectives, a controlled, replicated, and fully randomised percolation lysimeter approach was selected, on the basis of: i) feasibility (greatly reducing travel times compared to field studies); ii) potential disturbance (field sites risk disturbance by wild animals and humans). Additional benefits of the selected methodology were: i) identical environmental conditions facilitate comparison between the two degraded soils (the field sites are several 100 km apart with varying rainfall and temperature characteristics); ii) integration into a fenced-off meteorological station area (providing both security and meteorological data).

In the other hand, there were some limitations faced since it cannot replicate nature: i) short study period, unable to find further results; and consequently ii) lack of developed vegetation over the soil, which could have produced different results.

5.1 Study area

The experimental study area was at the University of Aveiro campus, specifically inside the fenced-off area of the meteorological station where the lysimeter park is integrated. However, the original soils came from two different locations, as shown on the following Figure 1**.**

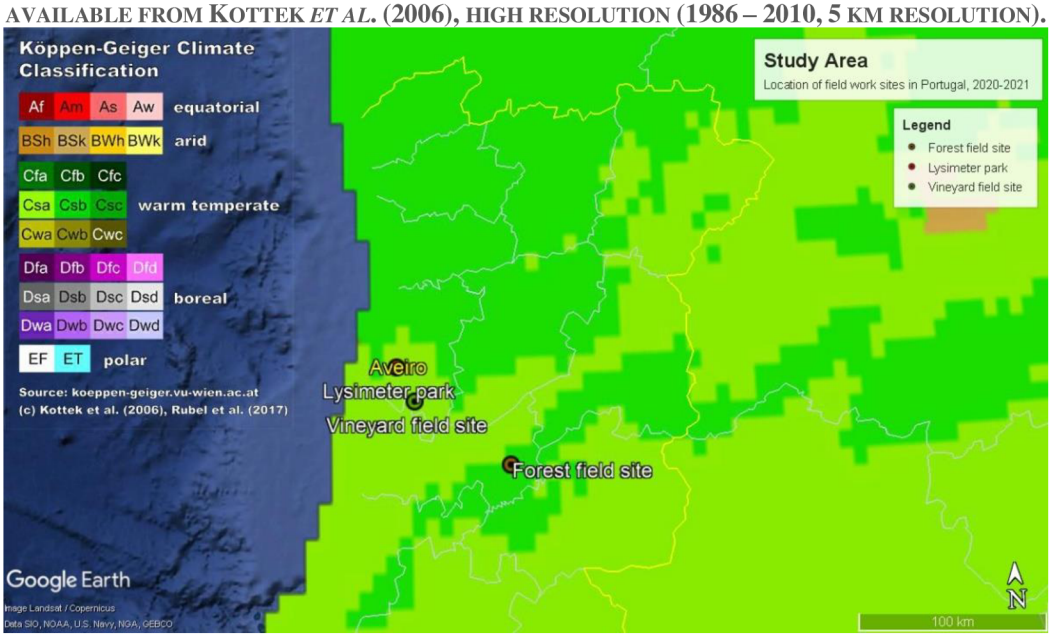
Figure 1. Study area location and workplace, hance lysimeter park was in aveiro portugal



In the district of Aveiro, it was located the lysimeter park at the University of Aveiro with an elevation of 4 meters; and the vineyard site (40°28'15.31"N, 08°33'0.35"W) at the elevation of 54 meters. The forest field site, as the Figure 1 show, was located south of the others, in the district of Coimbra (40°09'32.03"N, 07°57'34.86"W) at the elevation of 533 meters.

According to the climate classification of Köppen-Geiger, the whole central region of the country is classified as warm-summer Mediterranean climate. As seen on Figure 2, the classification differs from Csa to Csb. Meaning hot-dry summer classified as Csa, cool-dry summer as Csb.

FIGURE 2. STUDY AREA CLASSIFIED BY KÖPPEN-GEIGER CLIMATE CLASSIFICATION. CLASSIFICATION AVAILABLE FROM KOTTEK *ET AL.* (2006), HIGH RESOLUTION (1986 – 2010, 5 KM RESOLUTION).

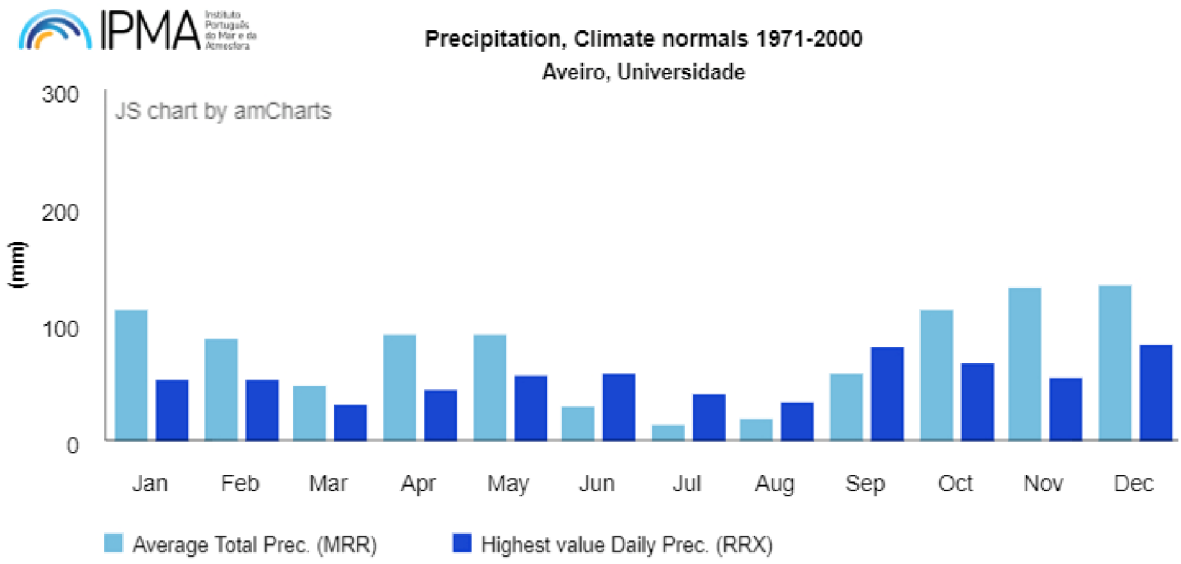


In keeping with Köppen-Geiger classification, "C" category stands for the temperature criteria which refers to months with lowest temperature average between -3°C and 18°C, opposite to the highest average temperature over 10°C. The "s", category assigned to seasonal precipitation, meaning dry summer season. During summer season, Aveiro district average precipitation is 11.8 mm; as for Coimbra district 12.8 mm. (Instituto Português do Mar e da Atmosfera (ipma.pt)) And finally, "a" for the University of Aveiro and vineyard sites, regards its additional temperature attributes, in this case, hot summer with hottest months average higher than 20.1°C; and "b", forest site location, mild-hot summer with the highest month average temperature up to 21.6°C.

Concerning the lysimeter park, throughout the period from October 2019 and September 2020, there were 11 rainfall readouts; and the obtained total volume was 840mm. This value means

an average of 76.4mm per rainfall event over this one-year course. Compared to the average total value of precipitation (Figure 3 below), the obtained value goes along with the climate normals; without exceeding any month average or retained under value.

FIGURE 3. PRECIPITATION AVERAGE TOTAL PER MONTH AND HIGHEST VALUES REACHED FOR EACH MONTH, BETWEEN 1971-2000 FOR THE STUDY SITE LOCATION.
HTTPS://WWW.IPMA.PT/EN/OCLIMA/NORMAIS.CLIMA/1971-2000/#102



The forest soils classification was an Umbric Leptosol. According to the International Union of Soil Science or IUSS (2015), Leptosols are described as stony and shallow, thin layer containing high portion of coarse fragments over continuous rock, usually with reduced volume of fine earth up to 20 percent. Typically found in mountainous terrains, medium or high altitude, hill slopes, on dissected topography and vegetated by grassland or forests (e.g., coniferous in acid soils); meaning it's azonal. The Umbric horizon characterizes this soil as thick, dark shade of colour, organic matter content level between intermediate to elevated, low base saturation (tending to acidity).

And the vineyard soil was a Dystric Regosol. The Regosols consist of unconsolidated mineral material, and because of so, are defined by what they do not have in their characteristics. Explained it so, Regosols are mineral soils not very thin neither very rich in coarse fragments, nor in sand, or fluvic materials (being excluded from all other classifications). Its profile development is usually low, when young age; or slow, due to arid conditions. Typically located in montane areas or arid and semiarid; areas under erosion and accumulation zones (which explains its minimal profile maturation – in different countries, this soil has been catalogued with distinct names to refer to "new/young" soil, in Brazil, *Neossolo*). Common landuse would be grassland, forest and intensive irrigated agriculture. (IUSS Working Group WRB, 2015:172)

Concerning its Dystric description of the latter soil, it refers to base saturation (or base chemical components abundance Ca, Mg, K, Na). In Dystric Regosols, its level of base content is low. Although Regosols can be deep soil, since it is young its horizons are not clearly defined and have low organic carbons, resulting in light-shade colouring which become hard when dry. (IUSS Working Group WRB, 2015:121)

Yet, in accordance with the Soil Ribbon Test steps with NRCS (Natural Resource Conservation Services) pyramid, the forest site soil was Loam type of soil, while the vineyard fits as Sandy Loam type - estimate soil texture was done by hands. Both soils were selected due its degradation. As mentioned before, they are generally found in eroding areas. In line with so, the vineyard soil presents high bulk density, very susceptible to and affected by soil compaction, reduction of water infiltration and retention capacity. Together with low soil organic carbon (SOC) content, this soil has been facing water erosion, organic matter loss, consequently biodiversity and functionality (Hakansson and Lipiec, 2000). As for the forest soil, acid and depthless, more vulnerable to erosion after wildfires recurrent in Portugal mainly during hot seasons (but not only).

5.2. Percolation Lysimeter Park

Fifteen percolation lysimeters were constructed for this experiment to enable the measurement of the drainage and chemical fluxes. For the soil-water sampling there were implemented chutes or runways, as shown on figure 4**.** With so, it was possible to collect the water from rainfall and the leachate into two different tanks**.**

FIGURE 4 LYSIMETER BOX WITH FOREST CONTROL SOIL. GUTTERS CONNECTED BY TUBES TO COLLECTION TANKS ARE VISIBLE (TANKS HERE WITHOUT LIDS). ON THE GROUND, ONE BOTTLE WITH A WATER SAMPLE FROM EACH TANK. SEPTEMBER OF 2020

The percolation lysimeter distinguishes itself from weighing lysimeter on its methods. The latter one measures the weight of the whole lysimeter including soil and water and determines evaporation by weight loss. The percolation lysimeter uses inserted sensors (Howell, 2005). In these percolation lysimeters there were two sensors, to measure soil moisture content and soil water potential.

TABLE 1. FIVE TYPES OF TREATMENTS, THEIR CODES, AND ITS COLORS.

Types of Treatment	Code
Vineyard control soil, no biochar applied	VC
Vineyard soil with 4% (w/w) of biochar incorporated into the topsoil	VB4
Forest control soil, no biochar applied	FC
Forest soil with 2% (w/w) of biochar incorporated into the topsoil	FB2
Forest soil with 4% (w/w) of biochar incorporated into the topsoil	FB4

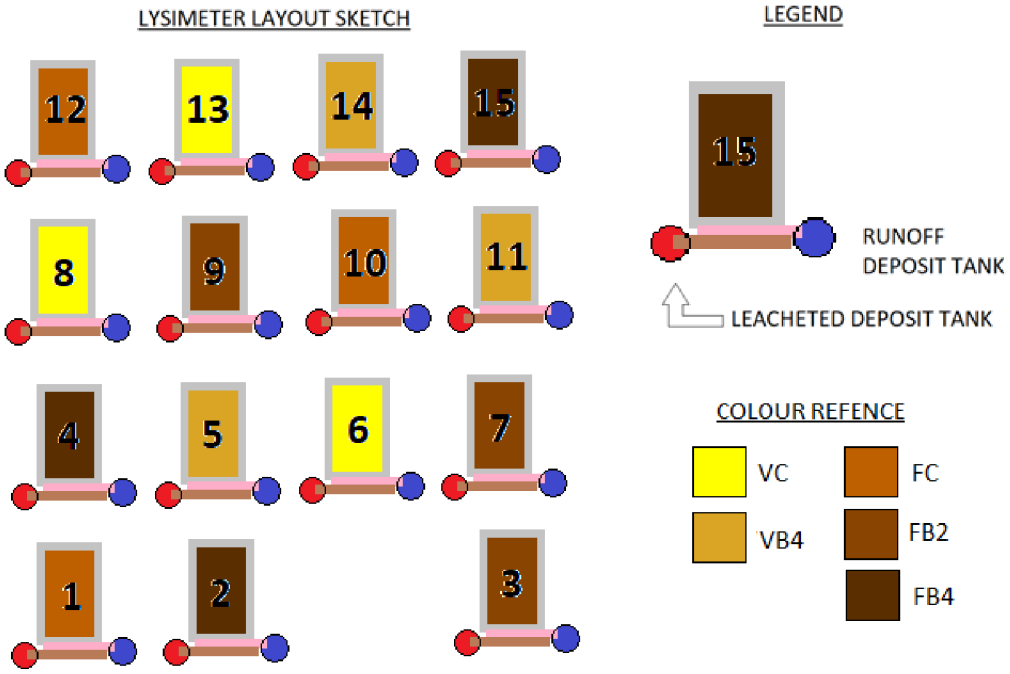
The 15 lysimeters containing 5 treatments (see Table 1) with three replicates each were located inside of the meteorological station at the University of Aveiro, as on figures 5.

FIGURE 5. LYSIMETERS AT THE METEOROLOGICAL STATION.

For the two chosen degraded soils, a biochar amendment of 4% (by weight) was selected based on the range of biochar application rates from a global meta-analysis (Jeffery *et al* 2017) and the low pH values of both soils (sufficiently low to avoid the risk of over liming) as on Table 7 (in Appendix). For the forest soil a second biochar application rate of 2% (by weight) was selected based on the already expected low bulk density of this soil (Table 8 in appendix), as on Table 1.

The five treatments (with 3 replicates) were applied to the 15 lysimeters in a fully randomised design (figure 6).

FIGURE 6. LAYOUT SKETCH OF THE LYSIMETERS IN THE METEOROLOGICAL STATION.



The lysimeters were installed in June 2019 and were kept outdoors under natural conditions, without addition of nutrients or fertilizers. Nets were used to cover the lysimeters to prevent birds from digging the soil (figure 7).

FIGURE 7. LYSIMETER WITH GROWING VEGETATION, COVERED WITH NET TO AVOID BIRD'S INTRUSION.

As seen on the figures 6 and 7, nets were used to cover the lysimeters. It became most necessary to protect the soil from birds which found to be digging the soil.

All lysimeters received a seed mixture designed to restore degraded soils (Fertiprado®, Vaiamonte, Portugal) in September 2019, harbouring the grass *Lolium multiflorum* and some legumes seeds *Trifolium subterraneum*, *Trifolium vesiculosum*, *Trifolium resupinatum*, *Trifolium incarnatum*, *Trifolium michelianum* and *Ornithopus sativus* (Jongen *et al* 2020). The same mixture was applied to all lysimeters for comparison.

Lysimeters were all at under the same weather conditions, being closely monitored. Rather different than if the experiment were only conducted on the field sites, with distinct conditions and susceptible to more variables. In this way, the replicates results can be compared.

5.3 Sample Treatment Method

All the samples were collected from the lysimeters, from each replicate by the end of 12 months. At each 10 samples, it was repeated one sample (replicate/duplication) to test accuracy and very method application.

For soil moisture content, soil organic matter, pH, electrical cconductivity, and experiments, with the use of a trowel, the sample collection and sieving (figure 8) were done by the same process: Each lysimeter was divided into two sections: top and bottom; due to erosion processes (erosion in the top and deposition and erosion in the bottom half), and to soil moisture conditions (drier on the top since there is nowhere for the water to go from the bottom). The latter reason is particularly important factor for chemical and biological soil processes. For each top and bottom sampling, they were twice collected; for representative sampling and calculated its average.

Figure 8. Sieving by hand with a 2 mm diameter sieve layer.

5.2.1. Soil Structure Methods

Mean Weight Diameter (MWD)

For aggregate analysis, the samples were air-dried for 20 days after collection (figure 9), under maximum of 30ºC; and sieved with the use of a sieve shaker machine. Into seven distinct diameters: 2 mm, 1 mm, 0.5 mm, 0.25 mm, 0.1 mm, 0.05 mm and minor than 0.05 mm. Each sieved section was weighed separately. The vineyard samples were sieved for 7 minutes, while the forest samples were 12 minutes long – during eh experiments itself, it was observed that due to each soil's particles weight and size took different period of time to be sieved. The speed used was 40 osc/min for both.

FIGURE 9. SAMPLES AIR-DRYING.

With a sieve battery (figure 10) it was separated into the following aggregate size fractions: 2–1 mm, 1–0.5 mm, 0.5–0.25 mm, 0.25–0.1 mm, 0.1–0.05 mm and <0.05 mm. The percentage by weight of aggregates at each fraction was used to calculate the mean MWD (Chaney and Swift, 1984).

MWD=*value1*/100*(2)+*value2*/100*((2+1)/2)+*value3*/100*((1+0.5)/2)+*value4*/100*((0.5+0.25)/2)+*value5*/100*((0.25+0.1)/2)+*value6*/100*((0.1+0.05)/2)+*value7*/100*(0.05/2)

Or

MWD = sum (value / 100 x (size fraction range)/2)

$$\mathrm{MWD} = \sum_{i=1}^{n} \bar{x}_i \, w_i$$

FIGURE 10. SETTING SAMPLES INTO SIEVING LAYERS FOR SIEVING MACHINE

Bulk Density (BD)

Bulk density samples were collected with the use of volume rings (small ring: 2.65 cm radius, 2 cm height; v = 44.12. And big ring: 2.5 cm radium, 5 cm height, V = 98.17). For each lysimeter half (top & bottom) a composite sample was taken, consisting of three ring volumes from random positions.

The samples were weighed immediately after its collection; oven dried at 105ºC and weighted once more, kept in thermal plastic bags that were weighed as well. The samples were not sieved and, therefore, included particles larger than 2 mm, such as stones and organic fragments. Bulk density was calculated by:

$$BD = (\text{oven-dry sample weight (g)}) \times (\text{Ring volume (cm}^3) \times 3)$$

FIGURE 11. SAMPLES WEIGHTING AND PREPARED FOR OVEN-DRYING IN THERMAL BAGS.

Soil Moisture Content (SMC)

The samples were collected by digging from surface into 7 cm (depth 0-7 cm total) from each lysimeter as mentioned before (equal to SOM, pH and EC sample collection). Samples were weighted before and after oven-dried for 24 hours at 105°C. (S.L. S.U. *et al* 2014)

The percentage of SMC was calculated by:

$$SMC = (\text{Weight inicial} - \text{Weight final}) / (\text{Weight final}) \times 100$$

5.2.2. Soil Chemical Methods

Prior to analysis, soil samples were sieved with a 2 mm mesh size and dried in an oven at 40°C. This fraction of soil was used to determine the pH, electrical conductivity and organic matter. Quality control of the chemical analytical procedures were ensured by testing every 10^{th} sample in duplicate and by the analysis of blanks that were prepared in a similar way to soil samples and run in parallel with samples.

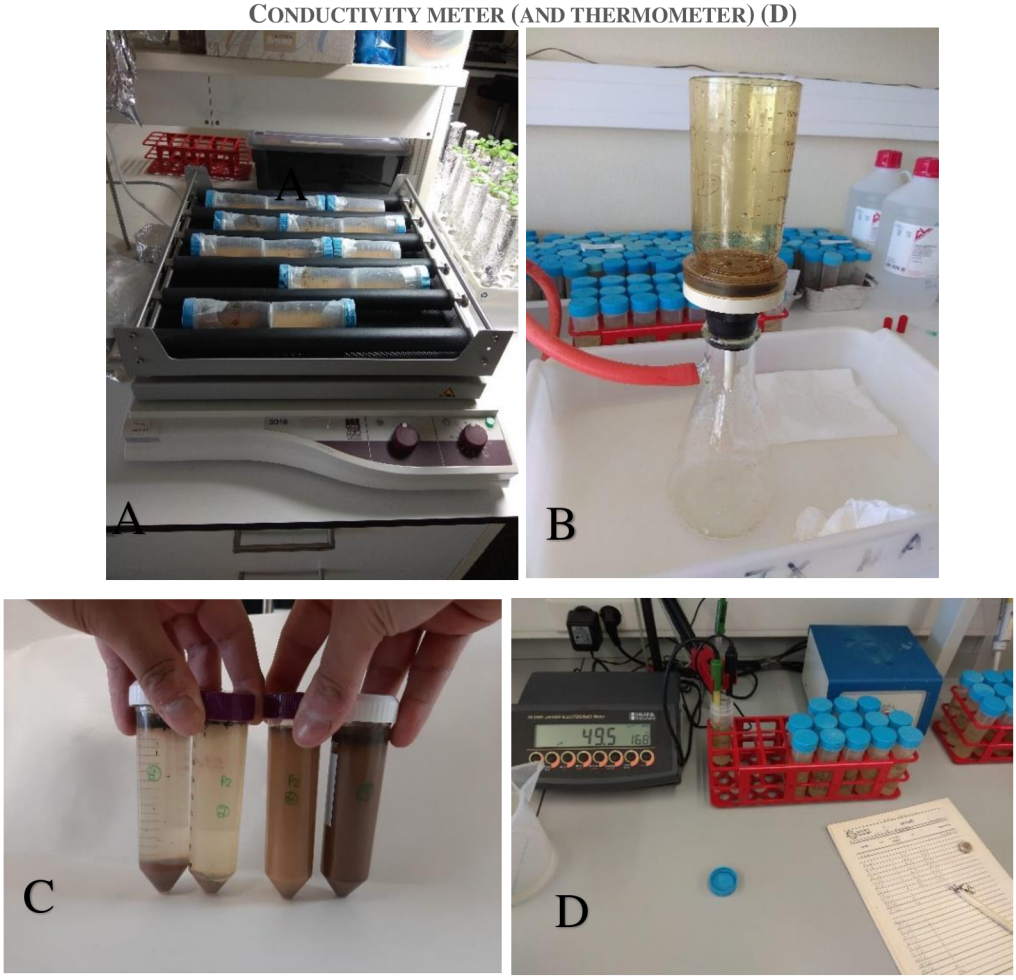
Soil pH

Soil pH was measured in Milli-Q water suspension of soil (1:5 v/v, solid to water) according to the methodology described in ISO 10390:2005 (ISO, 2005). Briefly, 5 ml of each soil sample were measure with a spoon to a polyethylene tube and added 50 ml of Milli-Q water. The suspension was mechanically shaken for 60 min, at a speed of 300 r.p.m., allowed to settle for at least 60 min (in order to let eventual floating particles to settle. After that, the pH of blanks and soil samples were measured using a pH meter, whilst being stirred (with a rate to achieve a reasonably homogeneous suspension of the soil particles) and after stabilization of the reading was reached. The pH value was recorded with two decimal places. Before the measurements of soil pH, the pH meter was calibrated using certified buffer solution of pH 4.00, 7.00 and 9.00 (20 °C).

Soil electrical conductivity (EC)

Electrical conductivity (EC) was measured Milli-Q water suspension of soil (1:5 m/v, solid to water) according to the method described in ISO 11265:1994 (ISO, 1994). Ten g of soil were weighted and transferred to a shaking bottle, and 50 ml of Milli-Q water were added and placed in the shaking machine. After 30 minutes shaking at a speed of 300 rpm, the samples were filtered through a filter paper (with low ash content). Electrical conductivity was measured on the filtrates with a conductivity meter, with a conductivity meter and the measurements corrected at a temperature of 25 °C. Prior to the conductivity measurements, the conductivity meter was calibrated using a certified reference solution.

FIGURE 12 SHAKING MACHINE (A); FILTER (B); SAMPLES AFTER AND BEFORE CENTRIFUGATION (C); CONDUCTIVITY METER (AND THERMOMETER) (D)



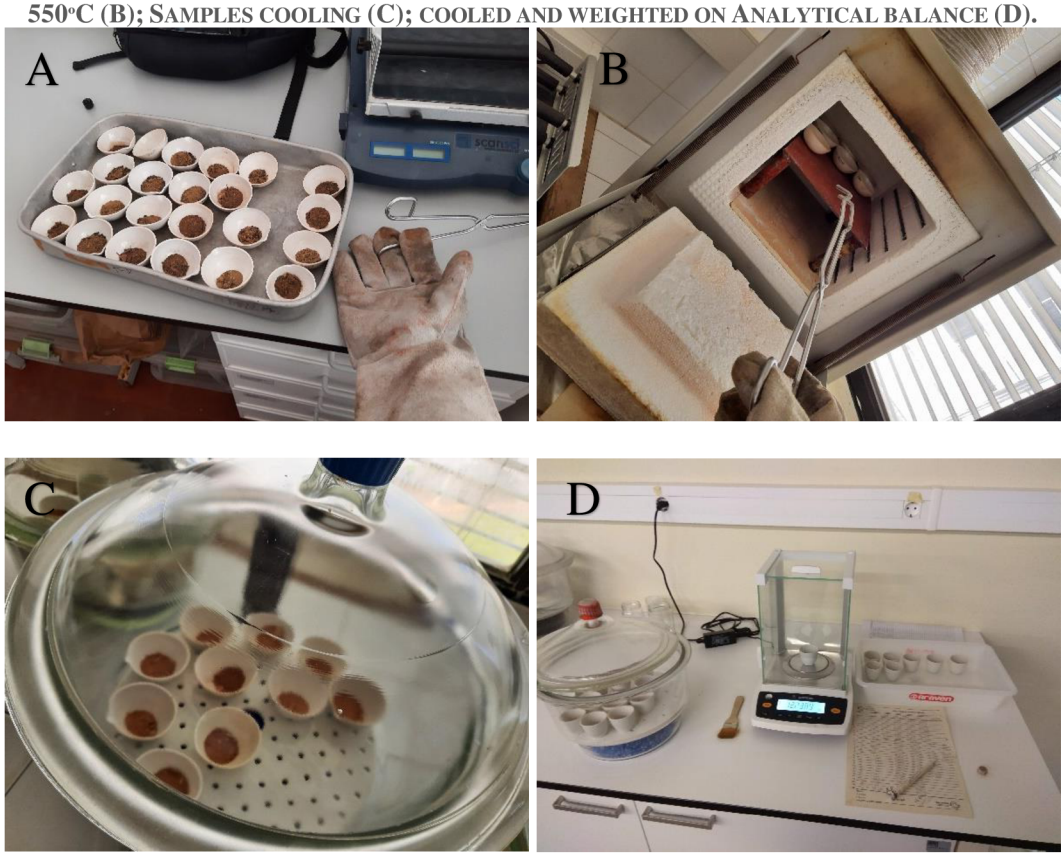
Soil Organic Matter (SOM)

Soil organic matter content was determined by the loss on ignition method (M. J. J. Hoogsteen *et al.* 2015). The samples were hand-sieved, dried in the oven for 24 hours at 105ºC, and weighed. The oven-dry samples were subsequently put in the muffle furnace for 4 hours at 550ºC to oxidize the organic matter, equilibrated in the desiccator, and weighed again (figure 12).

SOM contents (%) was calculated by dividing the weight loss of the sample at 550 degrees C by the oven-dry sample weight and multiplying by 100.

SOM (%) = (final weigh sample/ oven-dry weight sample) x 100

FIGURE 13. SAMPLE AFTER BEEN TAKEN TO OVEN AT 105 °C (A), SAMPLES BEEN TAKING INTO OVEN AT 550°C (B); SAMPLES COOLING (C); COOLED AND WEIGHTED ON ANALYTICAL BALANCE (D).



6. Results

For all treatments (Table 2), soil samples were taken from the bottom and top halfs of each lysimeter, analysed individually, and subsequently averaged for each treatment. The following tables and graphs were done based on the tables in Appendix with colour-coded treatments for clearer data understanding (Table 2).

TABLE 2 LEGEND AND ABBREVIATION OF SAMPLES AND TREATMENTS

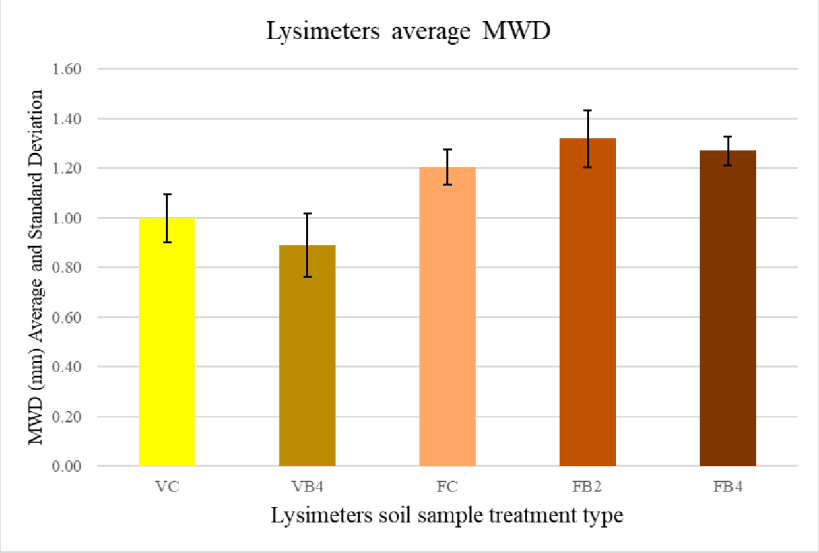
Legend	
b	bottom
t	top
VC	Vineyard Control soil sample
VC4	Vineyar soil sample with Biochar - 4%
FC	Forest Control soil sample
FB2	Forest soil sample with Biochar - 2%
FC4	Forest soil sample with Biochar - 4%

6.1.Soil structural results

6.1.1. Mean weight diameter (MWD)

Overall, the average MWD for the forest derivation samples were increased under both biochar treatments. And the 2% treatment presented highest rising on MWD average number, as seen on Table 3. Nevertheless, with the 4%, vineyard sample had its average MWD reduced. This happened in both sections - top and bottom - values (**Error! Reference source not found.**). However, none of these effects appear to be significant.

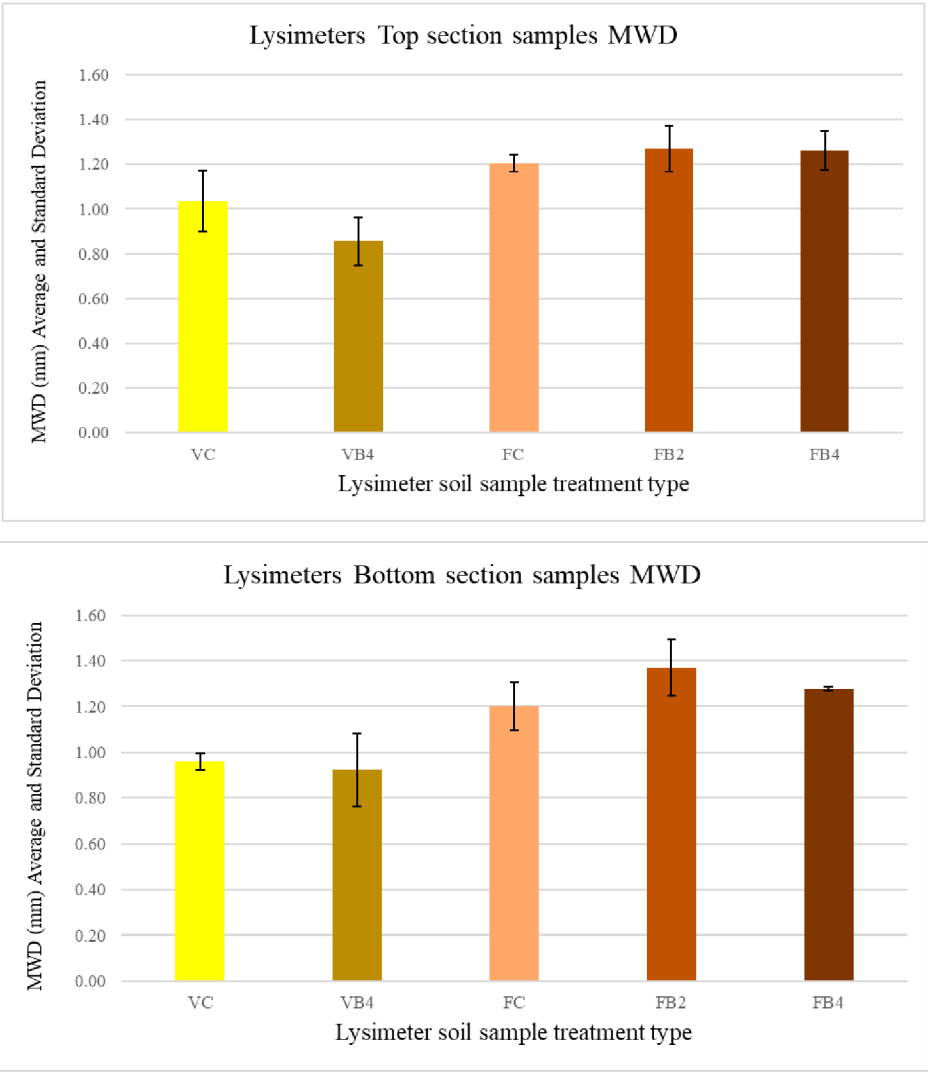
TABLE 3 LYSIMETERS SAMPLES AVERAGE MWD PER TREATMENT



For the forest soil had a general rise in its values, but comparing between treated samples, the FB4 had a slight smaller increasing on MWD. This was the same for the two lysimeter parts.

In the Figure 14 it was possible to see that forest control soil sample already had higher MWD average value than the vineyard control sample, and although with the 4% biochar treatment not as high as with 2% on forest soil, its result had higher values in both sections than the vineyards ever had.

FIGURE 14 LYSIMETERS SECTIONS TOP AND BOTTOM AVERAGE MWD



The increase with 2% on FB2 however showed lower for top section, which was the lysimeter part that only eroded through the 1-year experiment and deposited in the bottom part. In this way, the FB2 heighten in 4.95% on top part and 14.16% on the bottom. Although very subtle,

the FB4 increased more the bottom average MWD than the top as well, as for top in 4.13% and bottom in 5.83%.

As for vineyards samples, the MWD decreased in 17.30% and 4.16% with VB4.for top and bottom in sequence. The 17.3% is possibly related with the erosive process as well.

The soils with biochar presented opposite results comparing vineyard and forest's soils, once the vineyard with biochar 4% MWD values were not higher nor similar to forest biochar's samples.

6.1.2. Bulk density results (BD)

Biochar significantly decreased soil BD in the vineyard soil, but no significant effect was observed for the forest soil (Figure 18 Lysimeters individual average BD and treatment grouped**Error! Not a valid bookmark self-reference.**).

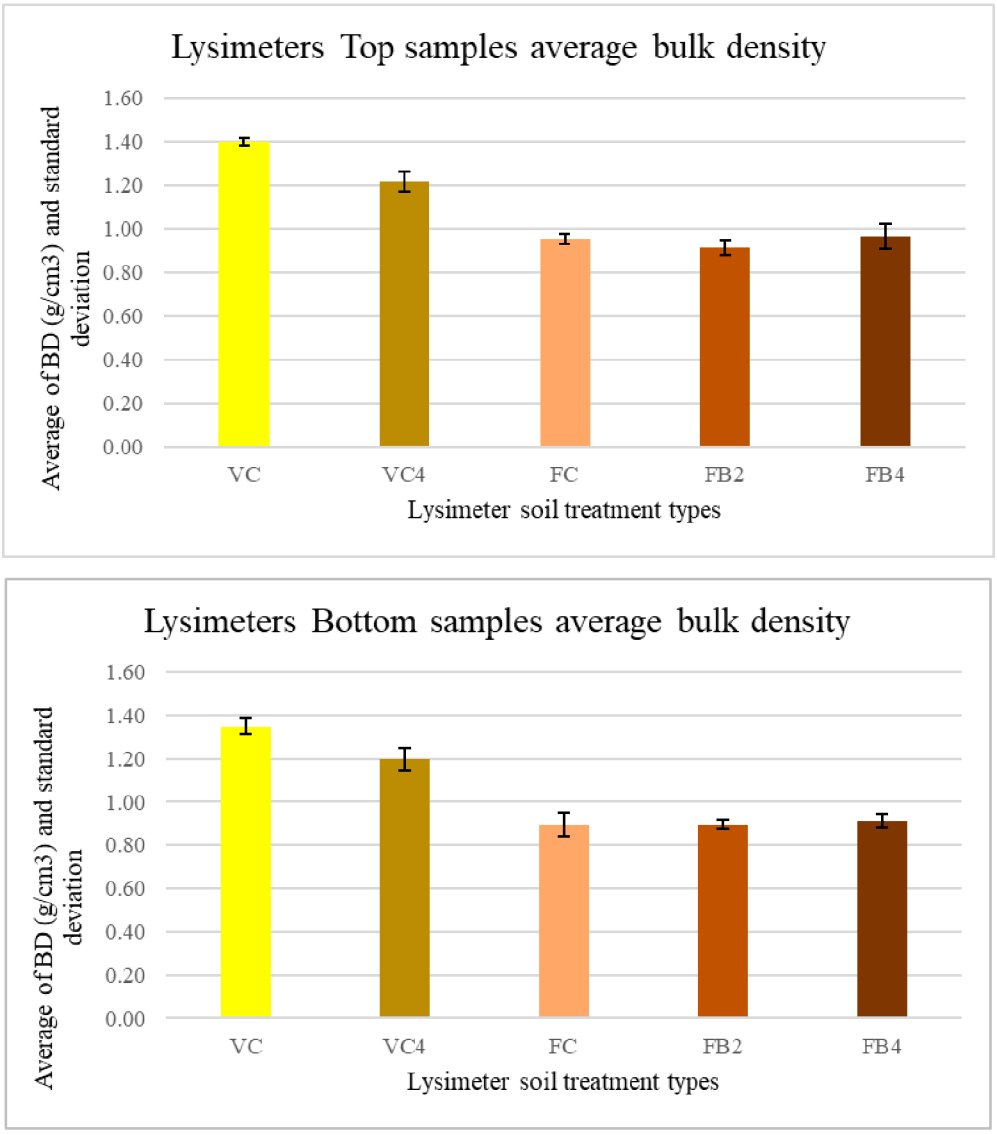
In any case, the VC values were the highest ones meaning with higher density. Looking into the sections (Table 4), its average BD got reduced in both parts with the biochar treatment - 13.57% and 11.11% top and bottom in sequence.

TABLE 4 LYSIMETERS SECTIONS AVERAGE BD

Lysimeters section samples average bulk density						
Treatment	Top			Bottom		
	av BD (g/cm3)	SD	COV%	av BD (g/cm3)	SD	COV%
VC	1.40	0.02	1.35	1.35	0.04	2.87
VC4	1.21	0.05	3.72	1.20	0.05	4.25
FC	0.95	0.02	2.61	0.90	0.06	6.29
FB2	0.92	0.03	3.82	0.89	0.02	2.18
FB4	0.97	0.06	5.96	0.91	0.03	3.47

Forest samples kept mostly the same values, with 3.15% (top) and 1.11% (bottom) reduction with biochar 2% application rate, making the soil less dense. With FB4 its density increases lightly by 2.10% (top) and 1.11% (bottom)

FIGURE 15 LYSIMETER SECTIONS AVERAGE BULK DENSITY



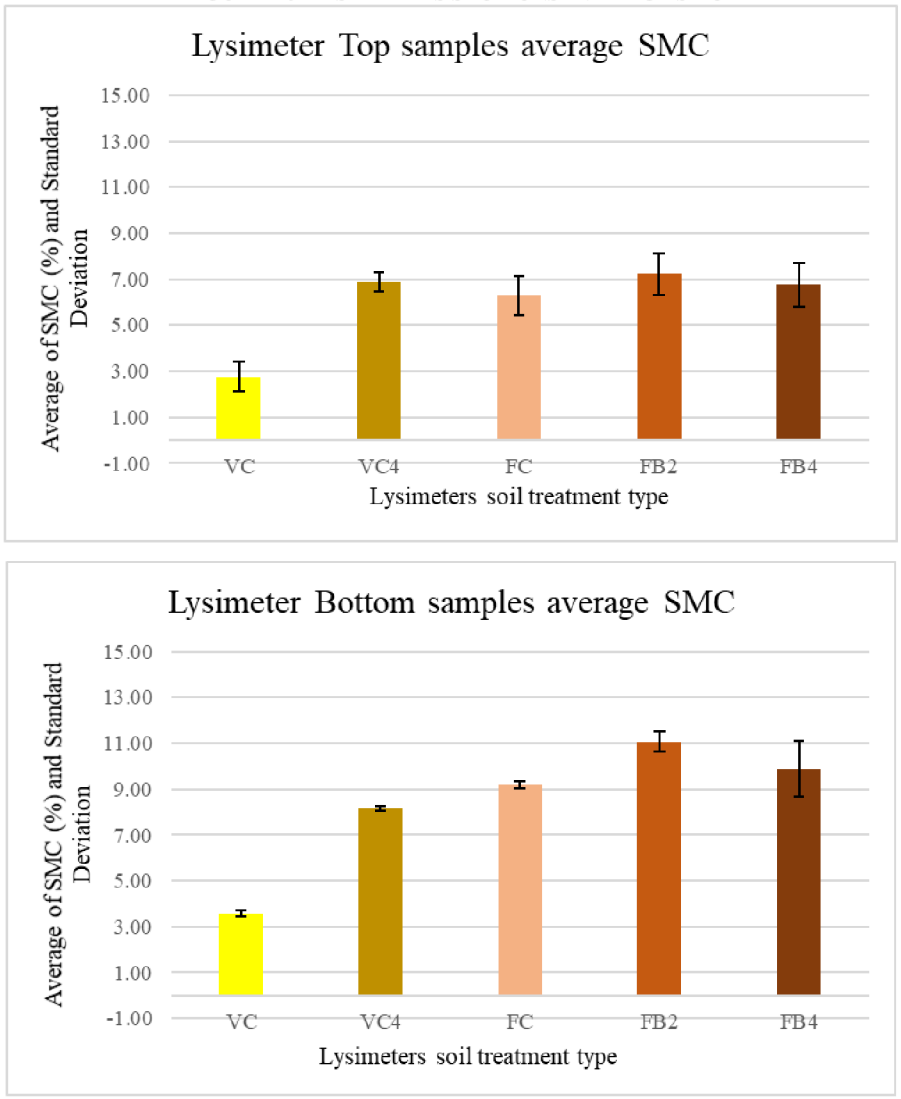
6.1.3. Soil moisture content (SMC)

The percentage of SMC in the soil at the time of sampling was significantly increased for the biochar treatments in both the vineyard and forest soils (Table 12 Lysimeters samples original weight samples and SMC percentage for each lysimeter), and the lysimeters parts presented diverse treatment effect.

From VC samples top and bottom, the SMC was observed to be double with biochar application compared to the control (**Error! Reference source not found.**

The forest soil samples had similar results from biochar treatment on both lysimeters sections, as for vineyards samples. FC samples SMC were already high in comparison to VCs, but still had their percentage risen (Figure 16).

FIGURE 16 LYSIMETERS SECTIONS AVERAGE SMC



On samples FB2 top and bottom there were a 14.62% and 20.47% raise in its SMC. Meanwhile, FB4 result was lower than FB2, with no significant change (increasing in approximately 7% for the two of it). These results affirm distinct outcomes for same biochar rate, however resulted into increasing of SMC in all scenarios.

The graphs (Figure 16) expose the absolute value difference between top and bottom. Only VC had similar values in both sections. The FC bottom had 31.48% higher SMC without any biochar rate, which leads to consider the lysimeter structure for some types of soil. Nevertheless, the biochar effect on vineyard soil on top part was undeniable, suggesting study field for the combination of biochar application with relief topography.

6.2.Soil chemical results

6.2.1. Soil pH results

As for the forest soils, the higher the biochar rate application in the treatments, the higher was the pH values of soils. The FB4 increase was 18.31% in relation to FC (Table 5). A significant change from acid– which was expected from Umbric Leptosol – towards less acid pH scope.

For vineyards soils, VB4 average value was 11.45% higher than for VC. Though not foreseen from Dystric Regosol (likely to be base saturated), the control sample already had a pH range closer to neutral and kept within the neutral range with the biochar.

TABLE 5 AVERAGE PH VALUES RESULTS FROM LYSIMETERS

Lysimeters average pH values per treatment			
Treatment	av pH value	SD	COV %
VC	6.20	0.39	6.29
VB4	6.91	0.21	3.04
FC	4.86	0.28	5.76
FB2	5.43	0.14	2.58
FB4	5.57	0.24	4.31

When comparing within the sections, the vineyard and forest derivation samples had similar values for both sections, suggesting that erosive process, SMC nor BD, lysimeter structure had much impact or influence on its pH (Table 6).

TABLE 6 LYSIMETERS SECTIONS AVERAGE PH VALUES

Lysimeters sections average pH values						
Treatment	Top			Bottom		
	av pH	SD	COV %	av pH	SD	COV %
VC	6.13	0.39	6.36	6.28	0.40	6.32
VB4	6.85	0.22	3.18	6.98	0.19	2.78
FC	4.89	0.30	6.23	4.84	0.28	5.84
FB2	5.38	0.15	2.70	5.49	0.12	2.27
FB4	5.49	0.26	4.71	5.65	0.19	3.36

6.2.2. Soil electrical conductivity results (EC)

The EC samples presented an extended range of values, in this way it was not information-wise interesting to provide top and bottom average. Nevertheless, according to the Appendix K Table 14 Lysimeter EC by sample, the values were between 16-65 (µS/cm), for all samples, with and without biochar treatment. There was no statistical analysis performed and no obvious changes could be noticed on the obtained results.

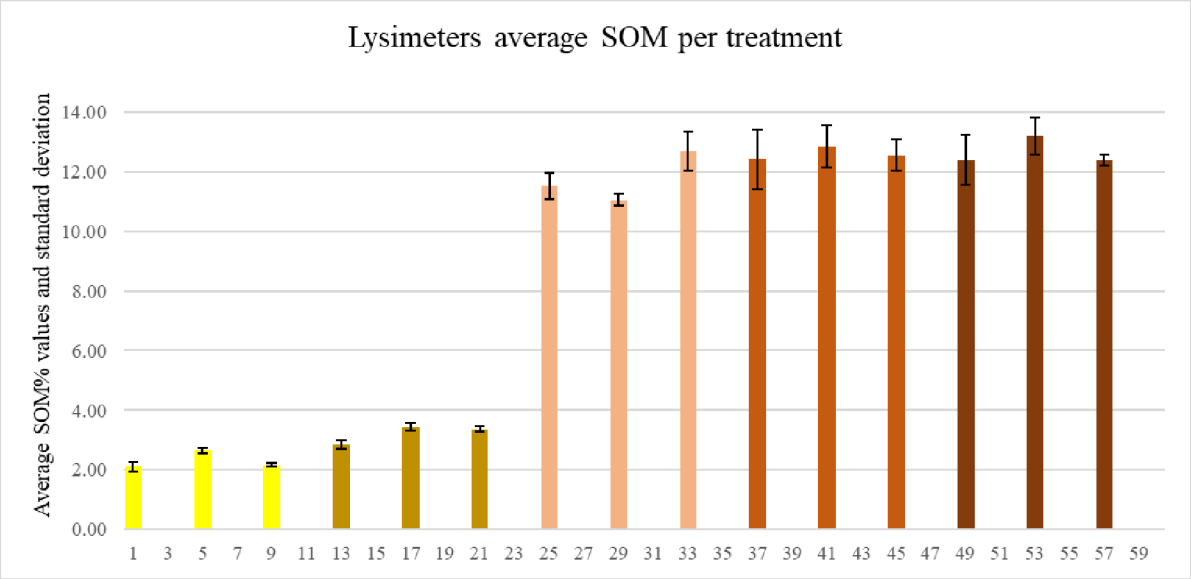
6.2.3. Soil organic matter results (SOM)

Results (Figure 17) showed that the content of SOM was much higher in FC soil than in VC soil. Furthermore, the application of biochar treatment to soils, had a strong effect in the vineyard soil and slightly effected the forest soil. Meaning different application rates of biochar had a strong effect in all parameters as shown in the Figure

The lysimeters that received the application of biochar treatment, presented higher values, mainly the vineyard (VB4), than the ones with no biochar treatment (VB and FC). Same effect could be observed for both sections.

The higher the biochar rate application in the treatments, the higher was the SOM percentage. The same behaviour was observed for pH, EC, SOC and SC. The application of biochar raised the SOC to more regular levels Also, SOC and SC concentrations were very similar, meaning that soil inorganic carbon (SIC) concentrations at the site were minimum, and apparently below the equipment limit of quantification. Soil inorganic carbon content remained low with increasing biochar rate applications, leading to the conclusion that biochar doesn't influence SIC as it does SOC. Finally, apart from Cu, all parameters are correlated to each other.

FIGURE 17 LYSIMETERS SOM



Biochar impacted on SOM% even on soil with high SOM%, FB2 and FB4 increased in 5-10% SOM on both sections' samples. And VB4 percentage heighten in approximately 40% vineyards SOM, both bottom and top (Table 16 Lysimter sections SOM).

However, between the sections there were no expressive differences in SOM indicating neither biochar or lysimeter topography-architecture influenced on percentage of organic matter in any parts. The induvial values in the Table 15 Lysimeters samples SOM % showed no significant dissimilarity within obtained results.

7. Discussion

In accordance with the conducted experiments and its results, biochar produced distinct effects on these two different types of soil. It was observed that biochar application had substantially stronger effects on the more degraded vineyard soil (low SOM %, sandy-loam texture) than on the less degraded forest soil, high SOM %, loamy texture). This can be explained by the greater potential for improvement in the selected soil quality indicators for the more degraded (vineyard) soil and, in part, it may be related to soil texture (Wang *et al*.,2017)

Vineyard soil that received the 4% biochar treatment rate had its SMC value doubled, which could relate to becoming less dense (Figure 15 Lysimeter sections average bulk density).

Upon addition of biochar, the vineyard soil had its SMC increased, decreased, BD decreased and SOM highten With so, biochar addition resulted in less dense soil, which means enhanced aggregation and higher porosity, higher water intake and, since SOM was increased, water holding capacity, thus decline on soil loss. Meaning biochar changed the soil structure component of soil quality.

For both soils, biochar amendment resulted in significant increases in soil pH, after one year of monitoring. The observed effect sizes were in agreement with the findings of Jeffery et al. (2017) in their global meta-analysis. Moreover, considering the relevant ranges in soil pH, i.e. 4.89-6.85, it is expected that this liming effect will also have increased the availability of key micronutrients. Further research is recommended to further explore this issue.

Additionally, as declared earlier, there was a slight increase in pH of the acid forest soil derivations, same for Liu and Zhang (2012) experiment on acid soil. The forest soil here studied faced repetitive post-wildfire erosion, and its region main land use was forestry. Combining factor that takes effect on soils chemical composition thus in its ecosystem services (ES). Biochar can become an useful amendment tool, starting with pH change as not-contaminating option (Břendová *et al.* 2015).

The lysimeters were built with aluminum boxes, and it may have influenced in the soil structure. As to the bottom part, which presented lower bulk density for all the lysimeters, as a possible result from holding the water longer than the top part.

The lysimeters sections played an important role in the data analysis, it was considered as a factor the erosive process and influence on soils hydrological behavior. Outstanding results were focused on moisture content and bulk density. Both related to slope and soil texture as well, strongly related to biochar effectiveness. For example, the increase on FB2 BD noticed from the top section to the bottom section could be due to biochar's own mechanisms and erosive process.

In comparison between sections, the FC top was denser than bottom from start. And still, on FB2 bottom it became a little less dense. Overall, for the forest treatments, FB4 top reached the most dense value, and it was less dense than VC4 bottom (Figure 15); different results from biochar application are related to soils characteristics itself. Further research into other biochar rates on vineyard soils would contribute for additional investigations.

For upcoming experiments, the observations of this study suggest that it might be interesting to drill holes in the bottom wall for the water to allow better drainage and avoid the bottom half of the lysimeter experiencing wetter conditions than the top half. Nevertheless, lysimeters have been widely used in diverse scientific investigations and allowed replication of non-controllable environments in (closer to) laboratorial ambiance, providing study conditions and variables restrictions (Hakansson and Lipiec, 2000).

Although soil biology was beyond the scope of this study, it seems likely that with the alterations made and based on other studies, biochar would also improve soils conditions necessary for microbial activity. Further research is recommended.

Forest soils had relatively small or no effect by adding biochar in all conducted experiments, but there was also no deteriorating effect. Between FB2 and FB4, the subtle, but still changes, were obtained with the 2% rate treatment. This suggests further research into the vineyard soil with addition of 2% of biochar for better comparison and understanding on biochar rate and compatibility with different types of soil.

8. Conclusion

In this research, the addition of biochar to forest and vineyard degraded soils increased specific and overall soil quality. As recall, biochar had bigger impact on vineyards soil derivation, specially on its bulk density and moisture content (structural indicators), and in its organic matter (chemical index). Some effects were stronger in distinct parts of the lysimeters, notably on the bottom section, as in SMC.

Hence biochar impacted in different level on each soil type. Regarding forest soil, biochar's application in two different proportions (2 and 4%) resulted in, both scenarios, light changes. Though small, the pH increment was significant. Yet, biochar improved its aspects, there were no quality deterioration. The 2% rate produced interesting results on forest soil, advocating for experiments in vineyards soil with the same rate.

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Appendix

Appendix A

TABLE 7. VALUES OF PH MEASURED FROM LYSIMETERS

Lysimeters and original soil samples - top and bottom (0-7cm depth)	
pH values	
Soil type treatment	pH value
L6T0-2	6.33
L6T2-7	6.24
L6T2-7	6.19
L6B0-2	6.29
L6B2-7	6.38
L6B2-7	6.28
L8T0-2	5.56
L8T2-7	6.22
L8T2-7	6.24
L8B0-2	6.2
L8B2-7	5.51
L13T0-2	6.69
L13T2-7	5.54
L13B0-2	6.83
L13B2-7	6.46
L5T0-2	7.14
L5T2-7	7.16
L5B0-2	7.27
L5B2-7	7.14
L11T0-2	6.7
L11T2-7	6.7
L11T2-7	6.61
L11B0-2	6.93
L11B2-7	6.79
L14T0-2	6.83
L14T2-7	6.81
L14B0-2	6.78
L14B2-7	6.98
L1T0-2	5.38
L1T2-7	4.73
L1B0-2	4.6
L1B2-7	5.12
L10T0-2	4.57
L10T2-7	4.92
L10B0-2	5.09
L10B2-7	4.6
L10B2-7	4.64
L12T0-2	5.07
L12T2-7	4.64
L12B0-2	5.2
L12B2-7	4.61
L3T0-2	5.35
L3T2-7	5.4
L3B0-2	5.62
L3B2-7	5.42
L7T0-2	5.51
L7T2-7	5.61
L7B0-2	5.61
L7B2-7	5.44
L9T0-2	5.39
L9T2-7	5.19
L9T2-7	5.24
L9B0-2	5.54
L9B2-7	5.3
L2T0-2	5.07
L2T2-7	5.25
L2B0-2	5.62
L2B2-7	5.31
L4T0-2	5.56
L4T2-7	5.45
L4B0-2	5.78
L4B2-7	5.62
L15T0-2	5.6
L15T2-7	5.82
L15T2-7	5.69
L15B0-2	5.75
L15B2-7	5.84

Appendix B

TABLE 8 LYSIMETER SAMPLES WEIGHT AND BULK DENSITY PER SECTION

Lysimeter soil samples (0-7 cm) weight (g) and samples BD (g/cm3)						
Lysimeter	Treatment	Plastic bag	Bottom sample weight (g)	Bottom samples BD (g/cm3)	Top sample weight (g)	Top samples BD (g/cm3)
1	FC	13.26	370.43	0.84	408.38	0.93
2	FB4	13.26	397.92	0.90	452.29	1.03
3	FB2	13.26	403.65	0.91	394.39	0.89
4	FB4	13.26	391.15	0.89	404.16	0.92
5	VB4	13.26	548.66	1.25	552.38	1.26
6	VC	13.26	604.25	1.38	618.79	1.42
7	FB2	13.26	387.09	0.88	396.21	0.90
8	VC	13.26	571.66	1.31	602.73	1.38
9	FB2	13.26	394.06	0.89	421.08	0.96
10	FC	13.26	418.36	0.95	428.92	0.97
11	VB4	13.26	505.51	1.15	514.12	1.17
12	FC	13.26	397.57	0.90	423.40	0.96
13	VC	13.26	593.02	1.36	612.39	1.40
14	VB4	13.26	522.28	1.19	528.73	1.21
15	FB4	13.26	417.18	0.95	419.66	0.95

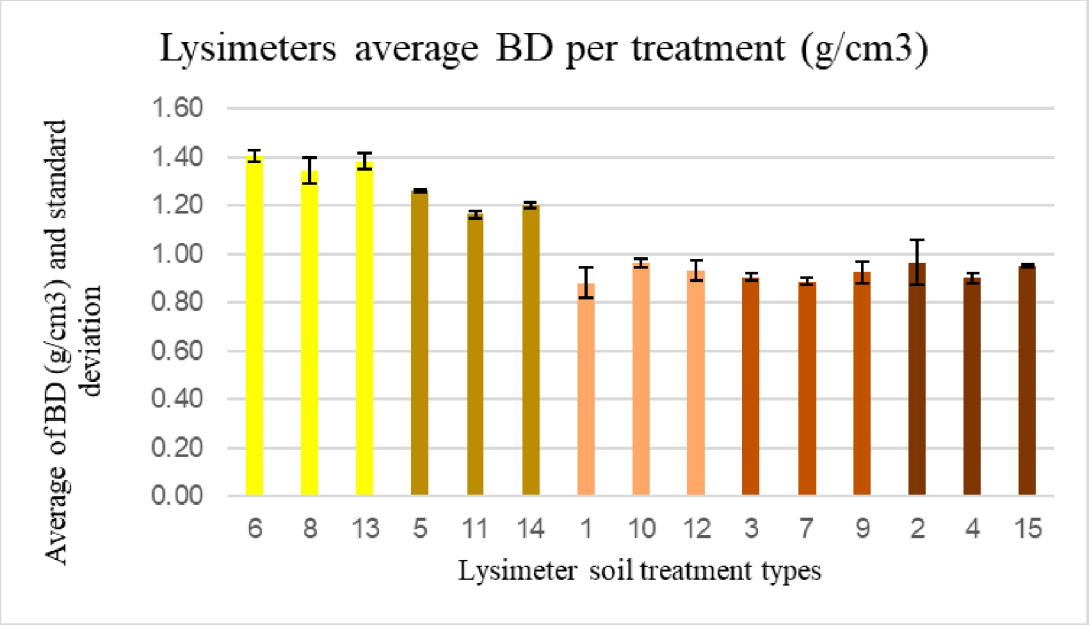
Appendix C

TABLE 9 LYSIMETERS AVERAGE BULK DENSITY GROUPED BY TREATMENT

Lysimeters average bulk density			
Lysimeter treatment	BD average (g/cm3)	SD	COV%
6	1.40	0.02	1.72
8	1.34	0.05	3.83
13	1.38	0.03	2.32
5	1.26	0.01	0.49
11	1.16	0.01	1.23
14	1.20	0.01	0.89
1	0.88	0.06	7.13
10	0.96	0.02	1.82
12	0.93	0.04	4.60
3	0.90	0.02	1.70
7	0.89	0.02	1.70
9	0.92	0.04	4.85
2	0.96	0.09	9.33
4	0.90	0.02	2.39
15	0.95	0.00	0.43

Appendix D

FIGURE 18 LYSIMETERS INDIVIDUAL AVERAGE BD AND TREATMENT GROUPED



Appendix E

TABLE 10 LYSIMETERS SAMPLES AVERAGE MWD PER TREATMENT

Lysimeter MWD per soil sample treatment			
Treatment	av MWD	SD	COV%
VC	1.00	0.10	9.85
VB4	0.89	0.13	14.32
FC	1.20	0.07	5.89
FB2	1.32	0.11	8.67
FB4	1.27	0.06	4.45

Appendix F

TABLE 13 AVERAGE MWD PER LYSIMETER SECTION

MWD Average per lysimeter section and treatment						
Treatment	Top			Bottom		
	av MWD	SD	COV%	av MWD	SD	COV%
VC	1.04	0.14	13.07	0.96	0.04	3.77
VB4	0.86	0.11	12.49	0.92	0.16	17.40
FC	1.21	0.04	3.20	1.20	0.11	8.75
FB2	1.27	0.10	7.95	1.37	0.12	8.85
FB4	1.26	0.09	6.95	1.28	0.01	0.65

Appendix G

TABLE 11 LYSIMETERS SAMPLING FOR MWD

Lysimeter samples weight (g) per sieve diameter											
Treatment		Weight (original)	2 mm	2-1 mm	1-0.5 µm	0.5-0.25 µm	0.25-0.1 µm	0.1-0.05 µm	<0,05 µm	bag (g)	Weight (sum)
1b	FC	108.65	53.08	12.84	9.77	10.18	10.01	5.28	0.63	5.37	107.16
1t	FC	545.71	208.20	78.22	63.22	85.62	65.19	30.25	5.79	4.55	541.04
2b	FB4	521.96	242.54	67.41	51.26	57.97	58.59	29.47	5.76	5.46	518.46
2t	FB4	99.91	44.92	10.36	8.80	7.72	8.81	8.45	4.05	5.60	98.71
3b	FB2	441.07	279.33	33.21	37.13	36.75	44.48	0.85	1.03	5.45	438.23
3t	FB2	453.86	218.89	61.58	61.52	57.32	44.64	0.76	1.41	5.38	451.50
4b	FB4	450.33	216.33	52.54	42.72	52.74	72.14	2.60	2.57	5.48	447.12
4t	FB4	446.42	195.19	59.74	45.58	47.97	85.75	1.55	2.55	5.39	443.72
5b	VB4	596.90	187.24	90.63	100.16	160.46	42.03	0.82	4.12	5.22	590.68
5t	VB4	665.46	160.61	102.28	110.27	205.14	66.54	0.92	8.17	5.46	659.39
6b	VC	530.00	117.08	108.17	99.40	123.29	57.04	0.60	16.25	5.63	527.46
6t	VC	495.23	102.25	100.55	90.45	119.18	56.14	0.51	15.82	5.37	490.27
7b	FB2	384.25	204.63	40.81	31.18	28.93	55.01	4.02	12.26	5.38	382.22
7t	FB2	292.84	116.14	39.89	31.00	28.43	55.49	2.51	12.90	5.33	291.69
8b	VC	589.40	123.47	96.87	100.54	170.18	74.62	0.44	14.49	5.31	585.92
8t	VC	-	198.29	95.35	158.17	101.37	20.72	6.35	1.67	5.28	587.20
9b	FB2	389.77	176.55	52.73	37.17	45.44	46.25	20.67	2.46	5.27	386.54
9t	FB2	484.21	235.74	63.24	43.58	44.60	53.13	27.22	7.39	5.24	480.14
10b	FC	441.81	197.88	55.70	40.63	38.66	54.18	32.61	14.43	5.34	439.43
10t	FC	360.77	164.57	42.15	31.59	30.21	40.52	28.09	15.96	5.31	358.40
11b	VB4	568.02	95.44	91.28	105.08	176.52	55.86	24.50	10.96	5.44	565.08
11t	VB4	433.29	63.05	62.84	73.99	137.19	51.31	22.12	14.38	5.29	430.17
12b	FC	455.59	169.97	54.83	47.09	48.19	69.36	39.87	17.93	5.40	452.64
12t	FC	566.29	261.58	64.62	49.17	50.79	76.01	39.60	16.12	5.44	563.33
13b	VC	619.80	126.68	115.27	108.42	166.86	57.07	20.47	13.30	5.28	613.35
13t	VC	629.59	124.69	118.51	111.33	173.34	57.40	20.71	11.94	5.26	623.18
14b	VB4	587.30	87.67	84.54	102.37	195.54	76.38	18.24	12.35	5.27	582.36
14t	VB4	492.73	75.72	69.38	84.64	158.26	61.46	20.27	14.12	5.58	489.43
15b	FB4	484.57	235.80	54.55	40.75	43.19	65.12	23.50	13.85	5.39	482.15
15t	FB4	402.27	215.86	45.00	31.32	29.53	40.15	19.76	12.75	5.41	399.78

Appendix H

FIGURE 19 LYSIMETERS MWD

Lysimeter samples weight percentage (%) per sieve diameter and its MWD										
Treatment	% 2 mm	% 2-1 mm	% 1-05 µm	% 05-025 µm	% 025-01 µm	% 01-005 µm	% <005 µm	% bag	MWD	SD
1b	49.53	11.98	9.12	9.50	9.34	4.93	0.59	5.01	1.30	16.30
1t	38.48	14.46	11.68	15.83	12.05	5.59	1.07	0.84	1.16	11.90
2b	46.78	13.00	9.89	11.18	11.30	5.68	1.11	1.05	1.27	14.96
2t	45.51	10.50	8.92	7.82	8.93	8.56	4.10	5.67	1.19	14.26
3b	63.74	7.58	8.47	8.39	10.15	0.19	0.24	1.24	1.50	22.26
3t	48.48	13.64	13.63	12.70	9.89	0.17	0.31	1.19	1.34	16.26
4b	48.38	11.75	9.55	11.80	16.13	0.58	0.57	1.23	1.29	16.21
4t	43.99	13.46	10.27	10.81	19.33	0.35	0.57	1.21	1.23	14.82
5b	31.70	15.34	16.96	27.17	7.12	0.14	0.70	0.88	1.11	12.34
5t	24.36	15.51	16.72	31.11	10.09	0.14	1.24	0.83	0.98	11.40
6b	22.20	20.51	18.85	23.37	10.81	0.11	3.08	1.07	1.00	9.51
6t	20.86	20.51	18.45	24.31	11.45	0.10	3.23	1.10	0.98	9.41
7b	53.54	10.68	8.16	7.57	14.39	1.05	3.21	1.41	1.35	17.95
7t	39.82	13.68	10.63	9.75	19.02	0.86	4.42	1.83	1.15	12.82
8b	21.07	16.53	17.16	29.04	12.74	0.08	2.47	0.91	0.93	10.17
8t	33.77	16.24	26.94	17.26	3.53	1.08	0.28	0.90	1.19	13.15
9b	45.67	13.64	9.62	11.76	11.97	5.35	0.64	1.36	1.26	14.64
9t	49.10	13.17	9.08	9.29	11.07	5.67	1.54	1.09	1.31	15.88
10b	45.03	12.68	9.25	8.80	12.33	7.42	3.28	1.22	1.22	14.00
10t	45.92	11.76	8.81	8.43	11.31	7.84	4.45	1.48	1.22	14.25
11b	16.89	16.15	18.60	31.24	9.89	4.34	1.94	0.96	0.86	9.89
11t	14.66	14.61	17.20	31.89	11.93	5.14	3.34	1.23	0.79	9.38
12b	37.55	12.11	10.40	10.65	15.32	8.81	3.96	1.19	1.09	10.89
12t	46.43	11.47	8.73	9.02	13.49	7.03	2.86	0.97	1.23	14.63
13b	20.65	18.79	17.68	27.20	9.30	3.34	2.17	0.86	0.95	9.40
13t	20.01	19.02	17.86	27.82	9.21	3.32	1.92	0.84	0.94	9.57
14b	15.05	14.52	17.58	33.58	13.12	3.13	2.12	0.90	0.80	10.47
14t	15.47	14.18	17.29	32.34	12.56	4.14	2.88	1.14	0.80	9.76
15b	48.91	11.31	8.45	8.96	13.51	4.87	2.87	1.12	1.28	15.75
15t	53.99	11.26	7.83	7.39	10.04	4.94	3.19	1.35	1.36	17.81

Appendix I

TABLE 12 LYSIMETERS SAMPLES ORIGINAL WEIGHT SAMPLES AND SMC PERCENTAGE FOR EACH LYSIMETER

Lysimeters samples (0-7 cm) weight and its SMC							
Lysimeter treatment		Samples original weight (g)		Samples weight after 24h oven-dry (g)		SMC %	
		Bottom	Top	Bottom	Top	Bottom	Top
1	FC	404.77	437.81	370.43	408.38	9.27	7.21
2	FB4	442.50	477.93	397.92	452.29	11.20	5.67
3	FB2	448.68	425.33	403.65	394.39	11.16	7.85
4	FB4	425.58	433.56	391.15	404.16	8.80	7.27
5	VB4	593.90	590.91	548.66	552.38	8.25	6.98
6	VC	626.18	-	604.25	-	3.63	-
7	FB2	431.38	426.46	387.09	396.21	11.44	7.63
8	VC	592.67	622.13	571.66	602.73	3.68	3.22
9	FB2	435.76	447.03	394.06	421.08	10.58	6.16
10	FC	457.25	452.53	418.36	428.92	9.30	5.50
11	VB4	546.79	547.18	505.51	514.12	8.17	6.43
12	FC	433.30	449.52	397.57	423.40	8.99	6.17
13	VC	613.38	626.52	593.02	612.39	3.43	2.31
14	VB4	564.20	567.09	522.28	528.73	8.03	7.26
15	FB4	457.42	450.46	417.18	419.66	9.65	7.34

Appendix J

TABLE 13 LYSIMETERS TREATMENT AVERAGE SMC PER SECTION

Lysimeter average SMC per section						
Treatment	Top			Bottom		
	av SMC	SD	COV%	av SMC	SD	COV%
VC	2.76	0.64	23.32	3.58	0.13	3.59
VC4	6.89	0.42	6.09	8.15	0.11	1.36
FC	6.29	0.86	13.63	9.18	0.17	1.87
FB2	7.21	0.92	12.71	11.06	0.44	3.96
FB4	6.76	0.95	14.00	9.88	1.22	12.32

Appendix K

TABLE 14 LYSIMETER EC BY SAMPLE

Electrical conductivity (µS/cm) Soils from Lysimeters - Top and Bottom - (0-	
Soil type treatment	EC voltage (µS)
L6B0-2	53.20
L6B2-7	19.45
L6T0-2	24.10
L6T2-7	22.55
L8B0-2	37.80
L8B2-7	18.64
L8T0-2	65.60
L8T2-7	25.16
L13B0-2	42.70
L13B2-7	18.12
L13T0-2	24.67
L13T2-7	16.11
L5B0-2	34.40
L5B2-7	18.69
L5T0-2	34.90
L5T2-7	21.79
L11B0-2	52.10
L11B2-7	22.35
L11T0-2	39.30
L11T2-7	22.63
L14B0-2	35.10
L14B2-7	22.89
L14T0-2	34.00
L14T2-7	21.68
L1B0-2	37.40
L1B2-7	57.80
L1T0-2	32.80
L1T2-7	39.90
L10B0-2	28.28
L10B2-7	33.50
L10T0-2	32.00
L10T2-7	42.90
L12B0-2	34.90
L12B2-7	50.20
L12T0-2	29.59
L12T2-7	58.80
L3B0-2	35.10
L3B2-7	22.72
L3T0-2	31.20
L3T2-7	35.50
L7B0-2	29.22
L7B2-7	29.89
L7T0-2	30.20
L7T2-7	30.70
L9B0-2	30.00
L9B2-7	34.80
L9T0-2	34.90
L2B0-2	23.60
L2B2-7	28.75
L2T0-2	30.40
L2T2-7	33.00
L4B0-2	32.80
L4B2-7	30.60
L4T0-2	34.40
L4T2-7	39.70
L15B0-2	27.25
L15B2-7	25.66
L15T0-2	28.89
L15T2-7	30.00

Appendix L

TABLE 15 LYSIMETERS SAMPLES SOM %

Lysimters soil organic matter (0-7 cm)							
Treatment	Sample (initial weight - g)	Sample ovendry	final weight (g)	SOM %	av SOM/lys	SD/lys	COV%
L6B0-2	5.04	5.02	4.92	2.02	2.12	0.16	7.71
L6B2-7	5.10	5.00	4.89	2.26			
L6T0-2	5.07	5.05	4.95	1.94			
L6T2-7	5.04	5.00	4.89	2.26			
L8B0-2	5.02	4.96	4.82	2.75	2.65	0.09	3.38
L8B2-7	5.03	4.87	4.74	2.68			
L8T0-2	5.02	4.93	4.80	2.64			
L8T2-7	5.02	4.92	4.80	2.53			
L13B0-2	5.24	5.17	5.06	2.15	2.16	0.05	2.48
L13B2-7	5.40	5.21	5.10	2.10			
L13T0-2	5.43	5.40	5.29	2.18			
L13T2-7	5.22	5.12	5.00	2.22			
L5B0-2	5.04	4.83	4.68	3.06	2.85	0.15	5.18
L5B2-7	5.05	4.81	4.68	2.74			
L5T0-2	5.01	4.95	4.81	2.85			
L5T2-7	5.09	4.86	4.73	2.75			
L11B0-2	5.30	5.09	4.91	3.42	3.44	0.12	3.36
L11B2-7	5.37	5.08	4.91	3.38			
L11T0-2	5.26	5.12	4.93	3.61			
L11T2-7	5.17	4.90	4.73	3.36			
L14B0-2	5.26	5.02	4.86	3.27	3.37	0.10	2.92
L14B2-7	5.20	4.87	4.70	3.46			
L14T0-2	5.26	5.10	4.93	3.44			
L14T2-7	5.34	5.04	4.88	3.29			
L1B0-2	5.10	4.81	4.28	11.04	11.52	0.44	3.81
L1B2-7	5.07	4.54	4.02	11.39			
L1T0-2	5.04	4.83	4.27	11.55			
L1T2-7	5.02	4.67	4.11	12.10			
L10B0-2	5.19	4.87	4.32	11.19	11.05	0.19	1.73
L10B2-7	5.35	4.88	4.36	10.81			
L10T0-2	5.36	5.12	4.55	11.22			
L10T2-7	5.21	4.89	4.35	11.00			
L12B0-2	5.16	4.97	4.38	11.93	12.68	0.65	5.15
L12B2-7	5.37	4.89	4.25	13.17			
L12T0-2	5.14	4.94	4.33	12.34			
L12T2-7	5.25	4.87	4.22	13.27			
L3B0-2	5.00	4.58	3.95	13.78	12.41	1.01	8.12
L3B2-7	5.10	4.48	3.96	11.64			
L3T0-2	5.03	4.78	4.18	12.56			
L3T2-7	5.05	4.53	4.01	11.67			
L7B0-2	5.07	4.75	4.11	13.45	12.84	0.71	5.53
L7B2-7	5.05	4.52	3.93	12.97			
L7T0-2	5.03	4.82	4.18	13.12			
L7T2-7	5.09	4.63	4.08	11.82			
L9B0-2	5.08	4.70	4.08	13.29	12.55	0.52	4.16
L9B2-7	5.01	4.47	3.92	12.30			
L9T0-2	5.04	4.74	4.16	12.10			
L9T2-7	5.04	4.67	4.09	12.50			
L2B0-2	5.07	4.71	4.08	13.20	12.38	0.83	6.68
L2B2-7	5.03	4.55	3.99	12.24			
L2T0-2	5.01	4.74	4.20	11.29			
L2T2-7	5.05	4.69	4.09	12.80			
L4B0-2	5.10	4.84	4.18	13.60	13.18	0.62	4.67
L4B2-7	5.08	4.54	3.94	13.21			
L4T0-2	5.11	4.88	4.28	12.30			
L4T2-7	5.10	4.82	4.16	13.60			
L15B0-2	5.02	4.68	4.11	12.11	12.39	0.19	1.52
L15B2-7	5.09	4.56	4.00	12.43			
L15T0-2	5.04	4.79	4.19	12.50			
L15T2-7	5.10	4.63	4.05	12.52			

Appendix M

TABLE 16 LYSIMTER SECTIONS SOM

SOM Average per lysimeter section and treatment						
Treatment	Top			Bottom		
	av SOM	SD	COV%	av SOM	SD	COV%
VC	2.30	0.25	11.03	2.32	0.31	13.40
VB4	3.22	0.34	10.69	3.22	0.27	8.53
FC	11.91	0.84	7.05	11.59	0.86	7.45
FB2	12.29	0.54	4.39	12.91	0.80	6.18
FB4	12.50	0.75	6.00	12.80	0.61	4.80