Development of a Hybrid Coconut Fiber - Biochar Biomantle for Bioengineering Applications

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Abstract– Land uses in South America have undergone historical changes associated with the development of civil infrastructure and urban growth, particularly, human activities associated with development have caused large areas of erosion and the occurrence of landslide, increasing the socioeconomic risk to exposed communities in developing countries. Landslide susceptibility have been maximized by the effects of global climate change. An alternative for the recovery of eroded surfaces, including slopes, is the recovery of plant cover as part of bioengineering works using restoration mantles with biological components, also called bio-mantles. This work presents advances of a research focused on the combined effect of coconut fiber and the implementation of biochar for the development of a composed bio-mantle that seeks to promote a positive effect, at low cost, from environmentally sustainable materials on growth of plant individuals of the genus "Lupinus sp" under controlled conditions. We found that the coconut fiber - biochar biomantle setup had a very positive impact on the development of the plants, show a promising alternative for future applications on soil ecological recovery. Understanding the development potential of a combined coverture with coconut fiber and biochar is a topic of key interest for the development and maintenance of sustainable infrastructure and the recovery of eroded areas in tropical countries such as Colombia.

Keywords-- Biochar, Biomantle, Bioengineering, Erosion, Colombia.

I. INTRODUCTION

Colombia's socioeconomic and physical development has historically produced important changes in land cover and landuse [1][5]. The growth of activities such as mining, the unbridled exploitation of forests for resources such as timber and charcoal, and deforestation for agriculture and livestock have seriously affected ecosystems, generating a negative environmental impact, leaving abandoned areas with unstable slopes and deep erosion processes [5][7][11].

Erosion processes are not considered natural effects, on the contrary they are considered leftovers of anthropic intervention, this, together with a deficient management of its effects has magnified its impact, being a major environmental problem worldwide [3][5][11] where Bogotá is no exception, because in most of its surroundings lie disturbances with limiting factors for a restoration process [11][13][18].

Erosive processes that determine the degradation of slope stability conditions in soil and rock, contribute to the threat of mass movements accentuated by climate change that modifies hydrological regimes of the soil [7][10]. Colombia is a countryspecially vulnerable to erosion effects caused by human activity and reflected in climate change due to erosion conditions, which is why it is urgent to mitigate its effects on the country's infrastructure [13]. Figures 1 and 2 show some of the effects of erosion on land degradation and the early stages of slope instability.

Figure 1. Soil erosion phenomena near Bogota (Colombia). Source: Own

Figure 2. Cut slope on the Bogotá-Villavicencio Road, Colombia. Source: Own

Among the multiple effects caused by erosion there is degradation and reduction of soil physical properties together with the eventual loss of horizons, where losses of micronutrients and macronutrients essential for plant development, such as carbon, nitrogen, phosphorus, sulfur, magnesium, and oxygen, are reported [5][9][11].

However, to counteract these effects, multiple ecological restoration techniques have been used with the intention of reducing the effects of such disturbances, among which is the strategic planting of plant species in soil, including the application of grasses, herbs, shrubs, and trees [5][8][9] as techniques for the recovery of the vegetation cover. All these efforts are aimed at the functional, spatial, and structural restoration of ecosystems [1][12][14].

Nonetheless, carrying out a restoration process in affected soils is not simple, since to cause a plant succession process in the short or long term in a degraded soil it is necessary in most cases to initially condition the soil [1][14] to create an environment conducive to vegetation establishment [5][16][18].

There are several options for soil conditioning, usually by adding organic or inorganic substances that fulfill the function of soil fertilization and enhancement; among the most used organic material are compost, manures, biosolids, and to a lesser extent biochar, which has the capacity to change the physical and chemical characteristics of the soil, increasing water and nutrient retention [8]. On the other hand, among the inorganic substances used in the soil are macronutrients such as potassium, magnesium, phosphorus, and nitrogen [2][5].

Subsequent to soil conditioning, vegetation with characteristics that promote an eventual ecological restoration process are introduced, versatile plants with high tolerance to adverse conditions with characteristics such as nitrogen fixation, rapid growth, and, depending on the case, root systems that support unfavorable circumstances such as eroded soils [5], such as the genus Lupinus, a fast-growing, nitrogen-fixing shrub that in turn forms canopies that buffer the temperature and generate favorable conditions such as microclimates that are favorable for the establishment of new plants [4][12].

Bioengineering, which seeks to protect and recover parts of ecosystems such as slopes affected by erosion effects in a sustainable and interdisciplinary way, plays an important role in the recovery of soils and slopes degraded by erosion through the joint use of plant species and biomantles [15], thus supporting the restoration of ecosystems through revegetation practices of slopes [16][17].

The stabilization of slopes occurs in an articulated form, biomantles are composed of geotextiles, prefabricated structural composites of polymeric material arranged in various forms of organized or random weaving that has high functionality in stabilization processes which in turn, has a high resistance, its articulation with specific vegetation comprises an interdisciplinary solution to erosion effects [6][16].

Looking for other options to the use of geotextiles, it has been considered the possibility of implementing the use of natural and degradable fibers such as coconut fiber (Figure 3) and fique, such fibers have great potential since they spontaneously provide support for plant growth and root development while consisting of biodegradable organic matter that will eventually return to the soil in the form of nutrients [5].

Figure 3. Coconut fiber used as a biomant.

In the practice it is known that ecological restoration has previously implemented the use of biomantles in slopes together with the incorporation of seeds, where the need for constant irrigation in dry soils has been reported [5][12].

There are also multiple cases in which promising substances have been used to recover agricultural soils and mining remnants by dosing substances, such as the dosing of biochar in rotary corn and soybean crops in the eastern plains of Colombia, or the application of biosolids in the Soratama quarry, with the aim of improving soil conditions, obtaining a higher yield in cases of crop cultivation [9][10], and recovery in cases of restoration in quarry soils [2].

Taking into account this information, we propose as an interdisciplinary initiative the study of the action of a biomantle composed of coconut fiber in conjunction with the remedial action of biochar in the growth of plants involved in initial revegetation processes in degraded soils under controlled conditions, in order to obtain information about the effects of the fusion of these treatments, thus opening the possibility of developing studies in the future that will allow a wider knowledge in the area.

II. MATERIALS AND METHODS.

An experimental design was carried out with 2 types of set-ups, each with 5 replications, where, in polypropylene containers (34.4 cm x 20.2 cm x 11.8 cm) 2 kg of MH Soil (according to USCS system) were disposed, using 2 sections of 5 seeds of Lupinus sp were sown in parallel in each container.

Lupinus is a genus of legumes with palmate compound leaves that has a long petiole which flowers have a curious colour range, since it can vary between yellow, blue or white. It is widely used in ecological restoration thanks to its growth and root capacity to grab soil and fix nitrogen present in the atmosphere [5][13].

One of the setups was designated as control, the other was conditioned with biochar in proportions 1:10, dosing 200 g in each container, after which the surface was covered with coconut fiber as a biomantle (Figure 4.). The plants were transplanted to an area with larger proportions once they exceeded the height of the containers.

Figure 4. Biochar-coconut fiber setup.

In both treatments, 8 weekly samplings of the plants were carried out, where two individuals were randomly extracted from each box, and the following measurements were taken and averaged per treatment to measure their growth and development:

1. Total Length (Roots and Stem).

   This was taken by extracting the plants from the assembly, measuring the stem (cm) and the length of the root to the longest end.

2. Leaf Area

   It was taken by delimiting a square on a leaf, taking its area, weighing it, and extrapolating this value to the total weight of the leaves.

3. Total, Dry Mass

   The plants obtained were separated into leaves, stem, and roots, dried in an oven for 24 hours at 80 C, their weight in grams was taken, averaged and finally the TDS (total dry mass) was obtained.

Figure 5. Set-up with biochar treatment and coconut fiber as biomantle with control set-up, showing the distribution of seedsowing in both cases.

An statistical analysis of Kolmogorov Smirnov was carried out on each variable to see if the data had a normal distribution ($p<0.05$), after this a Levene test was made in order to confirm that the data had homogeneous variances, with this data a T test was carried out to compare measurements done.

III. Results and Discussion

Preliminary results show that values of total length and leaf area as a function of time are shown in Figures 5 and 6. When analyzing the values expressed by the control individuals, a constant growth was evidenced in general terms without showing really significant variations in order to accept an Hi ($p<0.05$), on the other hand, the plants present in the assemblies with biochar treatment together with biomantle showed an increase in values both in leaf area from sampling 5 and in total length of the plant, showing higher difference values on the T – test, which accepted an alternative hypothesis where the difference in means was not equal to 0, having a wide difference.

The total plant length located in the treated set-up has higher values possibly due to the capacity of atmospheric nitrogen fixation by Lupinus sp [5]. Legume that reports the capacity of recovering soil characteristics, among these characteristics the fixation of atmospheric nitrogen by means of specific symbiosis with microorganisms of the genus Rizhobium, those are extremely beneficial relationships, since it is known that the fixation of atmospheric nitrogen and its expression in the roots brings benefits in the recovery characteristics of the soil [4][12].

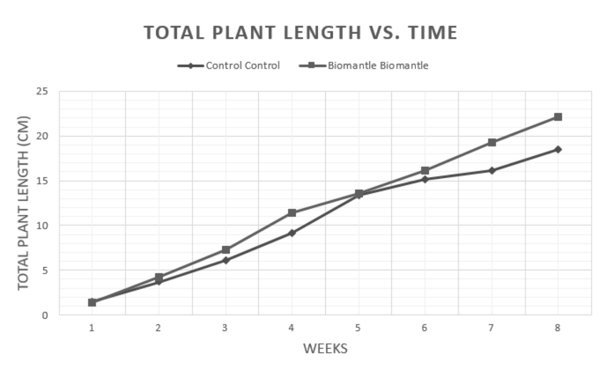

Figure 6. Total plant length vs time.

However, it is evident that the dry weight of the plants located in the treatment increases progressively with higher proportions (Figure 7.). It is known that approximately 90% of the dry weight is made up of indispensable elements such as carbon, hydrogen, and oxygen, it can be inferred that the presence of biochar in the conditioned set-up favored conditions for the proportions of carbon in the soil to increase together with other macronutrients essential for plant growth, reflecting this behavior [4][10].

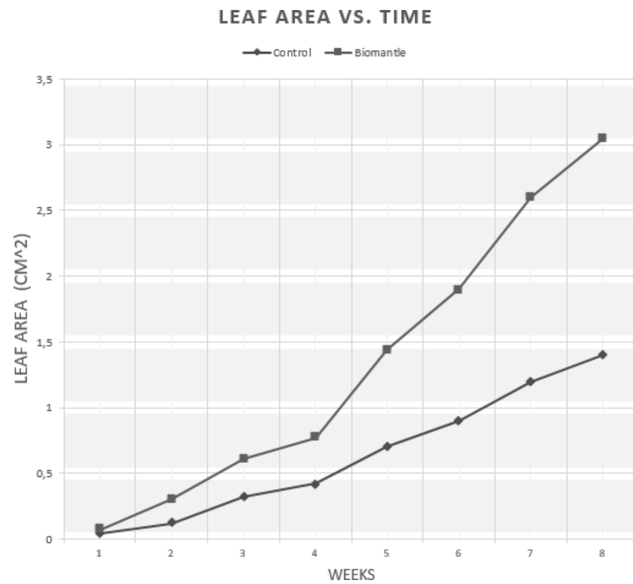

Figure 7. Leaf area vs. time.

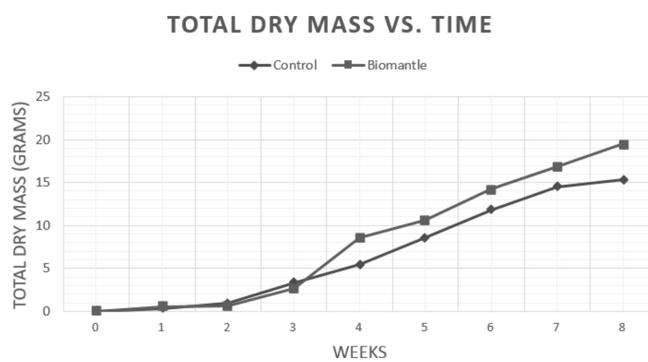

Figure 8. Total dry mass vs time.

The uptake of atmospheric nitrogen and the increase of carbon cause an important improvement in soil conditions, since the presence of essential elements such as macronutrients in individuals and in the soil imply better response conditions for abiotic stress [4][13]. Likewise, the presence of the biomantle implies a greater protection of the soil from external environmental factors such as rain and possible landslides [6][17].

IV. Conclusions

As it was observed, the behavior of the individuals present in the treatment of biochar together with coconut fiber showed a greater growth expressed in terms of total length, leaf area and total dry weight.

These values are indicators of the soil recovery effect of biochar, showing how its presence improves ground conditions for the growth of Lupinus sp. Likewise, the presence of coconut fiber provides optimal conditions that promotes the accumulation of nutrients used for plant growth, which together with the ability of Lupinus to capture nitrogen from the atmosphere generates an ideal microclimate for plant development of species with restoring potential in soils affected by erosion processes. Preliminary results show promising trends for future developments. In new stages of this research, other aspects will be reviewed in detail, such as chemical and physical soil characteristics and how they change during the development of the plants, getting specific knowledge about how humidity percentages change along texture and soil aggregates.

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