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Development:
Theories and
Application**

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Amanda da Silva
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PRESENTATION

Welcome to “Educational Development: Theories and Application”, an essential work for all those involved in the field of education. This book offers a comprehensive and accessible exploration of the theories and practices that shape educational development.

Aimed at teachers, students, professionals in the field and anyone interested in the subject, this reading provides an insight into the fundamental concepts that underpin modern educational practice. Throughout the text, you will find an analysis of contemporary educational theories and their practical applications, offering valuable tools for improving pedagogical practice and theoretical understanding.

Whether you are an educator looking for new strategies, a student in training or a professional committed to deepening your knowledge, this book will serve as a guide to understanding and implementing best practices in educational development. By exploring the topics presented, you will be better prepared to face the challenges and seize the opportunities in the field of education.

Get ready for an enriching journey that will not only broaden your view of educational development, but also offer applicable insights for turning theory into effective practice.

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CHAPTER 3

REVIEW AND PROSPECTS OF GEOTEXTILES: ROLE OF BABASSU FIBERS

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ABSTRACT: With the increase of global environmental changes and intensive anthropogenic activities, it is extremely important to maintain and improve soil function. Soil erosion is a naturally occurring process that affects all landforms. Different structures and forms of geotextiles are available to geotechnical engineers. Geotextiles in the form of woven and nonwoven structures are mostly used in various geo-engineering applications. This article focus on how the use of geotextiles have grown during the last decades and the importance of a particular material to be base of geotextiles, babassu (*Attalea speciosa* Mart. ex Spreng, Arecaceae) that is a palm with socioeconomic and ecologic importance found in humid tropical areas in Brazil.

KEYWORDS: babassu, geotextiles, soil stability, slope stability.

RESUMO: Com o aumento das mudanças ambientais globais e das atividades antropogênicas intensivas, manter e melhorar a função do solo se tornou extremamente importante. A erosão do solo, um processo natural, afeta todas as formas de relevo. Várias estruturas e formas de geotêxteis estão disponíveis para engenheiros geotécnicos, com geotêxteis tecidos e não tecidos sendo predominantemente usados em uma variedade de aplicações de geoengenharia. Este artigo se concentra no crescimento do uso de geotêxteis nas últimas décadas e destaca a importância de um material específico usado como base para geotêxteis: babaçu (*Attalea speciosa* Mart. ex Spreng, Arecaceae). Esta palmeira, encontrada em áreas tropicais úmidas do Brasil, tem importância socioeconômica e ecológica.

PALAVRAS-CHAVE: babaçu, geotêxteis, estabilidade do solo, estabilidade de encostas.

1 INTRODUCTION

Environmental changes challenge both biodiversity persistence and human wellbeing. The science and practice of restoration ecology, in collaboration with other disciplines, can contribute to overcoming these challenges. With the increase of global environmental changes and intensive anthropogenic activities, it is extremely important to maintain and improve soil function.

Soil erosion is a naturally occurring process that affects all landforms. Erosion, whether it is by water, wind or tillage, involves soil detachment, movement and deposition. Soil erosion contributes to the pollution of adjacent watercourses, wetlands and lakes. Soil erosion can be a slow process that continues relatively unnoticed or can occur at an alarming rate, causing serious loss of topsoil. Soil compaction, low organic matter, loss of soil structure, poor internal drainage, salinization and soil acidity problems are other serious soil degradation conditions that can accelerate the soil erosion process (<http://omafra.gov.on.ca/english/engineer/facts/12-053.htm>).

Depending of the case, permeable or impermeable barriers are a need in several engineering works, the last one in waste containment systems and effluents ponds, and compacted soils have been used for that purpose (Macambira, 2002). Slope stability prediction research is a complex non-linear system problem. Chuan et al (2013) made a slope stability calculation of open pit using 3Dslope software. More recently, Wang et al. (2022) using artificial intelligence, made predictions on slope stability based on visual exploratory data analysis of 77 in situ cases. Nie et al, (2022) propose a method of analysis with combining scaled boundary finite element method (SBFEM), strength reduction method (SRM) and polytree-based mesh refinement algorithm. Others, proposed the use of an ensemble learning techniques for the prediction of slope stability (Zhang et al., 2022).

2 GEOTEXTILES

Geosynthetics are man-made materials used to improve soil conditions. Most geotextiles consist of polymers of polyolefin, polyester or polyamide family, which involve environmental problems related to soil pollution. Geotextiles can be used for at least one

of the following functions: separation, reinforcement, filtration, drainage, stabilization, barrier, and erosion protection (Wu et al., 2020).

According to Brazilian legislation: “Geosynthetics - Generic term that describes a product in which at least one of its components is produced from a synthetic or natural polymer, in the form of a blanket, strip or three-dimensional structure, used in contact with the soil or other materials, in geotechnical and civil engineering applications” (NBR ISO10318-1:2018).

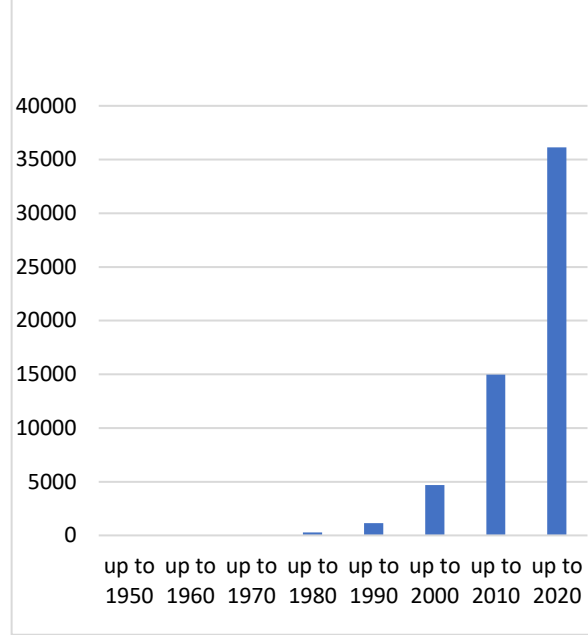
Geosynthetics are planar polymeric products, which are used in connection with soil, rock or other soil-like materials to fulfill various functions in geo-environmental engineering (Müller & Saathoff, 2015).

Geotextiles fall under the grand category of Geosynthetics. Geotextiles are high in strength to allow for maximum slope support, stabilization and erosion control, and there are three types of them: non-woven, woven or knitted. In particular, short-lived geotextiles find application as protection covers against soil erosion and revegetation aids, where plant growth is promoted until a natural green cover has established and the vegetation can take over the protective function. Usually geotextiles are placed at the tension surface to strengthen the soil (Morgan & Rickson, 2011).

Making a survey on databases, with just articles pair-reviewed published as a function of time, it is possible to see that the interest on studies on soil stability, slope stability and geotextiles correlate as expected. Figures 1- 3 display respectively those data. Present results evidence the multiple geotechnical applications of geotextiles mainly as slope reinforcement, or soil stabilization.

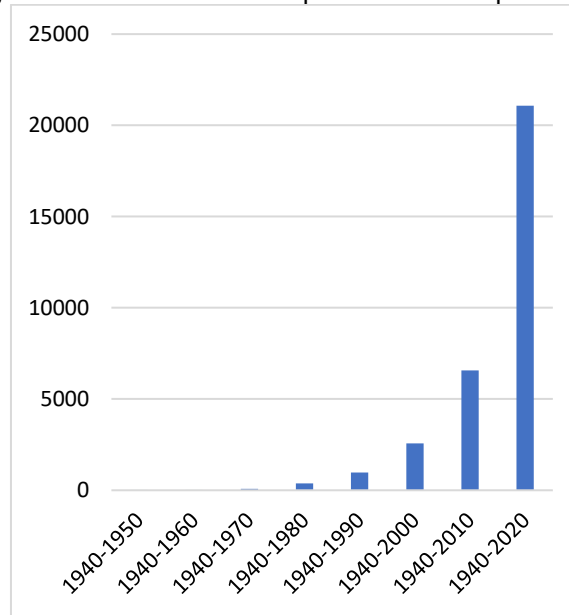
Systematically and academic interest on the mentioned subjects started in the last decades of the last century but had an extraordinary increment in the current one. The figures from the 2010 almost triplicate in the following decade.

Figure 1. Number of articles published on soil stability.



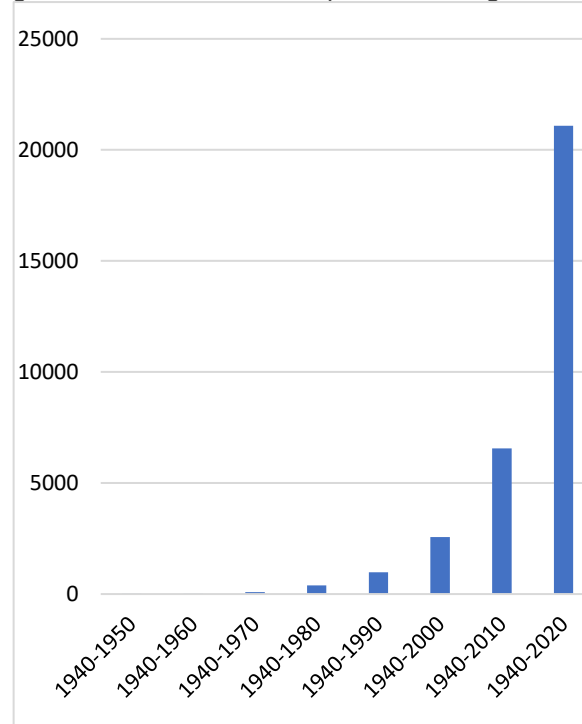
Source: The authors

Figure 2. Number of articles published on slope stability.



Source: The authors

Figure 3. Number of articles published on geotextiles.



Source: The authors

Different structures and forms of geotextiles are available to geotechnical engineers. Geotextiles in the form of woven and nonwoven structures are mostly used in various geo-engineering applications. Nonwovens are predominantly used for drainage, lining systems and asphalt overlay fabrics whereas the wovens are most frequently used for subgrade and base reinforcement, soil stabilization and separation, and sediment walls (Sengupta, 1991).

Some functional properties need to be satisfied by geotextiles:

1. **Mechanical properties.** This category covers properties such as tensile strength, breaking extension, modulus, abrasion resistance, bursting strength, frictional, bending and creep;
2. **Environmental properties.** This category covers chemical resistance, biological resistance, thermal resistance and resistance to UV degradation;
3. **Hydraulic properties.** In-plane water permeability and transverse water permeability properties are in this category.

Geotextiles market share, according to Desai & Kant (2016), were as follows: road construction, 44%, erosion control, 20%, drainage, 16% and others, 20%.

Kalore & Babu (2022) pointed out the importance of the design criteria for nonwoven geotextile to be used as filters with internally stable and unstable soils.

Reinforcement is probably one of the earliest application of geotextiles (Ingold, 1994). Geotextiles are used to increase soil stability, provide erosion control or aid in drainage. In roads and rail applications, they allow filtration and separation of granular layers. They are also used to protect membranes in landfill applications and in coastal defense applications, and Sabiri et al. (2020) described the performance of some nonwoven geotextiles on soil drainage and filtration.

Geotextiles processed to flexible material sheets are installed on various landscapes for reinforcing or protective purposes. Most applied materials in the field are non-degradable polymers, such as polyolefins or polyesters. The development of more environmentally friendly and biodegradable geotextiles is of interest for several application purposes. In general, there are two material classes available, which are natural fibers and biodegradable polymers. Geotextile fabrics, made of plant fibers, represent a promising approach and were already successfully installed in several applications (Prambauer et.al., 2019). However, the use of natural fibers also entails some limitations regarding water uptake and stability. Therefore, the potential use of a different material class, which comprises degradable, thermoplastic biopolymers, must be considered. There is only little information available on the use of these biopolymers in connection with geotextiles, thus their suitability regarding biodegradation, price and mechanical properties were evaluated.

A variety of lignocellulosic materials are applicable to produce biobased, biodegradable geotextiles (English, 1994). Natural fibre-based geotextiles can compete with polymeric geotextiles on both technical and economic grounds (Leao et al., 2012; Tanasa et. al, 2022). Basu et al. (2019) proposed bioengineering of river earth embankment using natural fibre-based composite-structured geotextiles.

As already mentioned, geotextiles can be produced from polyester or polypropylene polymers and or natural fibers. Vegetable or plant fibres have suitable properties to meet technical requirements cost effectively for use as natural geotextiles. Plant fibres can be classified according to the part of the plant as principal sources from which they are extracted: bast fibres, leaf fibres and fruit or seed fibres.

Highway construction broke the balance of ecological environment, especially in mountains areas. However, the plant community reconstruction at the highway slope can reduce the destruction effect, especially at the beginning of the project. Yang & Wang (2018), used three types of geotextiles including coir-straw blanket (CB), straw blanket

(SB) and nonwoven geotextile net (NG) to paved on highway slopes and the effects on soil erosion, the soil hygrothermal condition and vegetation growth were investigated. The results of field experiments, based on two years of research, showed that in artificial rainfall experiments CB, SB and NG could delay the time to runoff, reduce the runoff and decrease the erosion, effectively. The geotextiles as mulching material had multiple benefits including protected the topsoil and seeds from being washed away from the no vegetation covered slope, and enhanced vegetation growth by improving soil conditions, particularly in the beginning stage of slope vegetation restoration. In the mentioned work, the natural geotextiles effectively controlled runoff and soil erosion, although the effectiveness of the three natural geotextiles varied. For runoff control, straw blanket performed better than MCSB followed by CB. For soil erosion control, coir blanket was the most effective followed by MCSB and then SB.

Natural lignocellulosic fibers exhibit a good set of mechanical properties and their incorporation into polymers, not only leads to a reduction of the environmental impact of the compounds, but also to an improvement of biodegradability (https://books.google.com.br/books?hl=en&lr=&id=AwXugfY2oc4C&oi=fnd&pg=PP1&ots=gNN7TAZbPQ&sig=_MRCPhiG690gIIPjYF3yrTixZ69w&redir_esc=y#v=onepage&q&f=false.)

Although jute, sisal and coir geotextile products are currently available worldwide, also hemp, kenaf and African palm are also suitable raw materials for geotextiles (Leao et al., 2012; Gupta et al., 2018). Li et al. (2020) described that the use of plant-mat geotextiles, like palm-mat geotextiles, is an effective soil conservation strategy with promising application prospect and ecological profit.

In Brazil, there is a great variety of vegetal fibers with different chemical, physical and mechanical properties that can be used for the preparation of geotextiles. There are many Brazilian coir fiber suppliers and manufacturers. Fontes et al. (2021) evaluate the use of geotextiles made from natural fibers on the erosion control in the Lower São Francisco riverbank. The experimental trial was conducted for 12 months monitoring, taking into consideration two periods analysis: rainy and dry, in a riverbank of 16.6° performing an area of 12.4 X 4 m, in three blocks with the following treatments: *Typha latifolia* Geotextile (TG), *Juncus sp.* Geotextile (JG), *Syagrus coronata* Geotextile (SG) and Bare Soil (BS) without geotextiles, located on the right bank of the Lower São Francisco river downward, in the municipality of Amparo de São Francisco in Sergipe state, northeastern Brazil. The vegetation cover development, tensile strength,

deformation and sediments loss by runoff were evaluated. Among the tested geotextiles, the *Syagrus coronata* and *Juncus sp* geotextiles were more efficient in the erosion control producing a less amount of sediment, although on the resistance and durability of the fibers, *Typha latifolia* presented better results.

The potential of some other fibers remain little known like piassava (Elzubair & Suarez, 2012) or babassu (Franco, 2010).

3 BABASSU

Babassu is an erect perennial evergreen palm, reaching up a height of 15 to 30 m. The trunk is slender, ringed with leaf scars, 20-50 cm in diameter. It is a palm with socioeconomic and ecologic importance found in humid tropical areas in Brazil, especially in frequently burned and degraded landscapes (Ferrari & Soler, 2015). Babassu is native to Brazil, but also to Guyana, Suriname and Bolivia (USDA, 2010. GRIN - Germplasm Resources Information Network. National Germplasm Resources Laboratory, Beltsville, Maryland). The babassu palm is considered weed in pasture areas of “*Cerrado*”, the vast tropical savanna ecoregion in Brazil.

Various scientific names are usually found for the babassu in current literature: mainly *Orbignya phalerata* and *Attalea speciosa*, but also *O. speciosa* and *O. martiana*, among others. This multiplicity of names leads to great confusion in the scientific community causing mistakes to be successively propagated. According to Cavallari & Toledo, (2016) it is recommended the adoption of *Attalea speciosa* Mart ex. Spreng as the most suitable name for the babassu and highlight that a broad taxonomic review of the *Attalea* group is necessary.

Babassu is one of the most important non-timber forest resources of rural communities in the Amazon. Araujo et al. (2016) explored the ethnobotanical knowledge and uses of babassu by riverine populations inhabiting the Tucuruí Lake Protected Areas Mosaic in the eastern Amazon, by examining the diversity, purposes and descriptions of its uses and aspects of its extraction. Data were collected in 2010 and 2014 from 193 families. A total of 1,226 use records were cited representing 60 different uses. Records were classified into nine use-categories; utensils and tools were the most important category, followed by construction and human food.

Babassu oil has been used in South American countries for cooking and medicinal purposes. It also has industrial applications as a biofuel. In the United States, it's mainly used in skin and hair care products.

There are several uses for babassu oil; however, its potential for providing other industrial products remains unexploited, due to the lack of scale and production structure. The rudimentary nature of the babassu kernel extraction process employed by the peasantry has been blamed for being one of the key factors of the crisis in the babassu oil industry economy. Pinheiro & Frazão proposed in 1995 the use of a new model, instead the traditional one, for sustainable exploitation of babassu palm forests and integral fruit processing at the village and farm- level. The new model includes the coordination of fruit collection and storage, and the gradual replacement of the traditional system of manual breaking by mechanized integral processing at local level. The machinery consists of a dehusking machine (to separate epicarp and mesocarp), a breaking machine (to crack the dehusked fruits), and a machine to separate the small pieces of broken endocarp from the kernels. In 2015, Ferrari & Soler established conditions for the preparation of the raw material fruit of babassu for oil extraction by pressing and producing biodiesel by ethanolic transesterification. Oil and press cake were obtained through hydraulic and continuous press, biodiesel was produced and the quality of products was compared. The total of saturated fatty acid in babassu oil was between 78% and 82%, and the total of unsaturated fatty acids that promote good oxidative stability in the oil was in the range of 17% to 20 %. Oil obtained by cold pressing extraction and its biodiesel had better results in terms of quality. The quality of oils is within the Codex standard and biodiesel from oil extracted by cold pressing had higher oxidative stability.

Babassu is a source of biomass for energy and raw material in the manufacture of handicrafts. The babassu oil corresponds to only 7% of the total weight of the fruit; the other parts like the epicarp, the endocarp, and the mesocarp (93%) are underused as biomass. The babassu endocarp and epicarp have high content of fixed carbon, which makes them more suitable for carbonization and burning than the babassu nuts and mesocarp, which contain less than 5% fixed carbon.

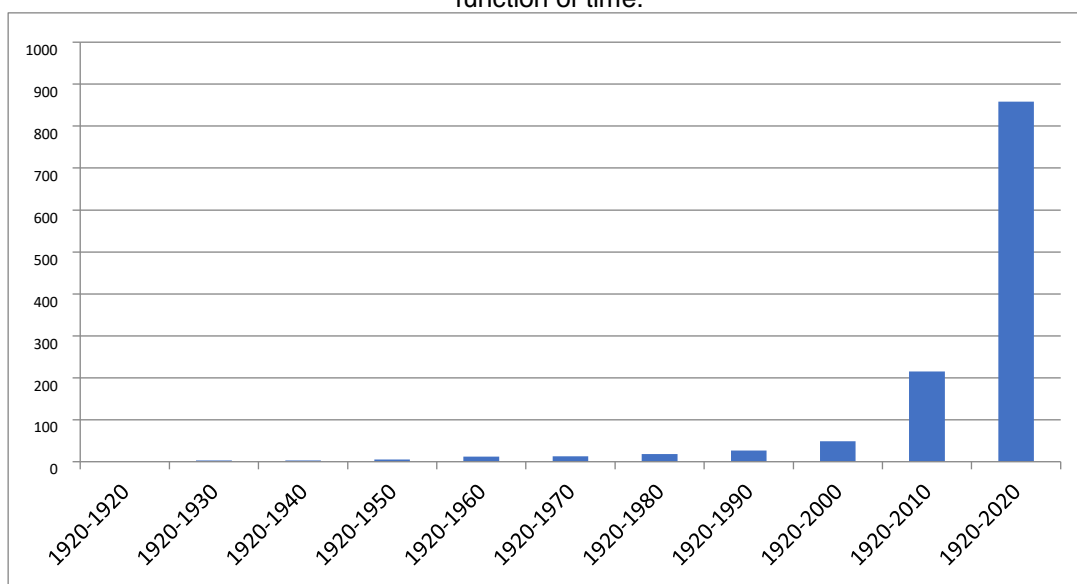
The babassu mesocarp is usually transformed into flour and used in animal feed. Also, babaçu by-products (endocarp, mesocarp, epicarp and activated carbon) can be

used as a potential adsorptive target species for inorganic and organic molecules (Teixeira, 2008, Silva et al, 2013, Maniglia et al. 2017; Silva et al, 2019).

According to Chaves et al (2023) babassu fiber has a chemical composition, of 28.53% lignin, 32.34% hemicellulose, and 37.97% cellulose. In addition, it showed a high crystallinity index of 81.06% and a microfibril angle of 7.67°. These characteristics indicate that babassu fibers have favorable chemical and morphological properties to be used as reinforcements in composites, highlighting its potential as an important material for applications in technology areas.

Although some articles were published as early as 1930 (Lee, 1930) and 1940, the interest in academic studies on babassu and all their multiple uses was very low until the present century. Fig. 4 presents the number of articles published in English that appeared online mainly peer-reviewed works according Web of Sciences database. It is evident the poor academic interest on this palm until the couple of last decades, but also the huge potential ahead of babassu fibers in terms of the present tendency.

Figure 4. Number of articles published online according to Web of Science database on babassu as a function of time.



Source: The authors

In the present century, new applications on babassu were described showing the impact of such increased interest. Raposo et al. (2021) developed formulations for polymeric alginate films with added starch from the babassu coconut mesocarp, fiber removed from the babassu coconut epicarp and glycerol, crosslinked with CaCl_2 , to be used as base materials to manufacture utensils such as biodegradable packaging and shopping bags.

Staufenberg et al., (2015) prepared biomimetic fibre-reinforced composites using babassu nut based on regenerated cellulose fibres (lyocell, L) with two different fineness values as reinforcement embedded in a polylactide (PLA) core matrix and polypropylene (PP) based outer layers. The biomimetic fibre composite reaches a significantly higher impact strength that is 1.6 times higher than the reference sample produced from a PLA/PP/L-blend. At the same time the hardness is slightly increased compared to PP/L.

The influence of thermoplastic starch and babassu mesocarp incorporation on the biodegradation of poly(butylene adipate-co-terephthalate), PBAT, PBAT/TPS blend, and its biocomposite were investigated by Nunes et al., (2019). The incorporation of thermoplastic starch and babassu mesocarp to poly (butylene adipate-co-terephthalate) led to a reduction in PBAT molecular weight on the blends and composite, but the reduction was higher on the blends than in the composite, while addition of thermoplastic starch accelerated biodegradation and incorporation of babassu retarded it. Mitjia et al. (2019) started a multidisciplinary research on the viability of the babassu palm eco-socio-system in Brazil, to enabling us to consider the best way to ensure its sustainability.

4 BABASSU AS A COMPONENT OF GEOTEXTILES

Fibers of babassu palm started to be described in promising experiments as adequate components to prepare bioblanket such as any other fibrous material like sisal (Sponga, & Coelho (2005). Costa et al., (2018) studied de degradation during processing of vegetable fiber compounds based on poly (β -hydroxybutyrate) (PHB) and poly (butylene adipate-co-terephthalate) (PBAT) blends, using materials obtained by grinding the outer layers of the fruit of the babassu palm tree.

Furtado et al. (2020) prepared a polymeric composite produced from fiber of babassu palm tree treated by mercerization and 5%, 10%, and 20% high-density polyethylene (HDPE) matrix. They studied the physico-chemical characteristics and evaluate the degradation of the polymeric composites. Polymeric composites, were characterized by FTIR, XRD, TG/DTG, SEM, AC impedance and traction test. Traction tests revealed that at a high fiber concentration of 20%, the mechanical resistance of the composites can decrease. After characterization, the materials were subjected to degradation processes via UV radiation. For comparison, a sample of an oxo-biodegradable plastic bag was evaluated under the same conditions. The incorporation

of babassu fiber into an HDPE matrix in the formation of a polymeric composite is promising for enhancing photo-oxidation degradation. Lemos et al. (2017) established the potential of natural fibers supplied by agroindustrial residues from sugarcane, wood and babassu to be used as reinforcement in biocomposites for various applications. Rodrigues (2019) described the preparation and properties of composite made from babassu coconut epicarp fiber plus polymeric residues.

A couple of years ago some experiments on the preparation of a babassu-based slope protection system were published (Bezerra, 2022).

5 CONCLUSIONS

The use of geotextiles, as showed in this work, have grown during the last decades employed in infrastructure, soil, construction, agriculture and environmental applications, been slope protection and restoration one of them. The basic concept of geotextiles dates back to ancient times when textiles consisting of locally available natural fibers employed to increase the stability of roads and soils. Nowadays, in spite of geotextiles made of synthetic fibers (geosynthetics) are considered a modern achievement, the return to the increasing use of plant fibers appears as a versatile tool for environmental sensitive applications in geotechnical engineering. Mainly in Brazil, babassu fibers seem to have a great potential to be use whether in the stabilization of soil, the river banks, ground reinforcement for civil infrastructure or filtration of water excess in farmlands and flood protection, hill slopes stabilization and drainage, as plant geotextiles are successfully performing in civil engineering and agriculture and becoming an increasingly viable alternative in many other applications.

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