Institution: University of Wolverhampton

Unit of Assessment: 12 Engineering

Title of case study: The environmental and socio-economic contribution of biogeotextiles to sustainable development and soil conservation in Maranhão State, Brazil

Period when the underpinning research was undertaken: 2000 - 2018

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Professor Michael Fullen	Professor of Soil Technology	1984 - Present
Professor Trevor Hocking	Professor of Plant Biology	1972 – Aug 2010, Oct 2010 – Aug 2012
Professor David Mitchell	Professor of Hydrology	1968 – Dec 2002, Jun 2003 – Mar 2007, Feb 2012 – Aug 2012

Period when the claimed impact occurred: 2013 - 2020

Is this case study continued from a case study submitted in 2014? N

1. Summary of the impact

Biogeotextile mats made from the leaves of Buruti palm trees (*Mauritia flexuosa*) were used to treat approximately 4,000m^2 of severely eroded gullied land within Maranhão State, Brazil. Over several years, the biogeotextiles stabilised the land and encouraged progressive regrowth of vegetation across over 50,000m^2. This benefited the area, both in terms of multiple environmental impacts, including increased resistance to soil erosion and increased floral and faunal biodiversity. Furthermore, socio-economic benefits to the local community included financial gain from the crops (leaves, fruit and oil) of Buruti palm trees subsequently planted in the area. Additional impacts were evident in providing stabilised land for the construction of multiple housing units and the development of environmental education programmes related to the project.

2. Underpinning research

The research underpinning this case study has been conducted since 2000, led by Professor Mike Fullen of the University of Wolverhampton, resulted in the creation of novel organic biogeotextile mats. These mats are designed to stabilise land, improve water conservation and decrease soil erosion. They are designed in a grid arrangement, usually as 50x50cm squares to allow them to be easily pinned into the ground. Traditionally, such mats have been made of synthetic materials, such as nylon. However, further research at the University of Wolverhampton led to the design of environmentally-friendly biogeotextile versions of the mats, made from organic materials (Figure 1). The following Findings [F] underpin the impacts claimed:

F1. Effectiveness of biogeotextiles for soil and water conservation

Initial research on geotextile mats began at the University of Wolverhampton in 2000, resulting in the following findings:

1. Geotextile mats can significantly decrease runoff and soil erosion rates by up to 98% [R1].
2. Field comparison of multiple biogeotextile fibres identified that the West African palm tree species *Borassus aethiopium* effectively decreases soil erosion rates [R1].

Following this initial research to analyse the effectiveness of these biogeotextile mats, a multi-national project named the 'BORASSUS Project' was launched in 2005. Led by Professor Fullen, this initiative also involved research institutions from Africa (The Gambia and South Africa), Asia (China, Thailand and Vietnam), Europe (Belgium, Hungary and Lithuania) and South America

(Brazil). Research from this project led to further refinements of these mats, investigating various organic fibres and uses within different environments, particularly in developing countries.

F2. Biogeotextile mats are effective in promoting soil and water conservation in Brazil

Further research confirmed the biogeotextile mats as an effective tool for reducing soil erosion. In particular, results highlighted the potential for their use on Brazilian humid-tropical soils:

1. Biogeotextile mats are highly effective in intercepting the kinetic energy of raindrops and thus decreasing rain-splash erosion [R2].
2. Biogeotextiles slow down the velocity of surface runoff and thus increase infiltration rates into soil systems. In turn, decreased runoff volume and velocity decreases soil erosion rates [R2].
3. The mats are suitable for and effective on Brazilian humid-tropical soils (Oxisols and Ultisols) [R3].

F3. Buruti palm leaves are an effective material for biogeotextile mats in Brazil

To ensure the mats were economically-viable in Brazil, a local and readily-available source of fibres was required for production. The Buruti (*Mauritia flexuosa*) palm tree was selected as a suitable option for the production of the mats (Figure 1). This Brazilian species is similar to the West African Borassus palm tree, which had been previously identified as an effective material for the mats [R1]:

1. The Buruti biogeotextile mats were effective for both soil and water conservation [R2, R3].
2. With careful woodland management, the crop of Buruti palm leaves was sustainable [R4].
3. The mats were inexpensive and thus economically-viable [R5].

F4. Biogeotextile mats are an effective tool for the rehabilitation of gullied land

Severely gullied land is a difficult substrate for natural vegetation to establish and grow. Findings identified that the biogeotextiles were effective in stabilising gullies and activating a progressive series of environmental benefits, e.g. increased soil organic matter and soil organic carbon contents, improved soil structure and stability, increased water infiltration rates and water storage in soils, and increased biodiversity of both flora and fauna) [R4, R5].

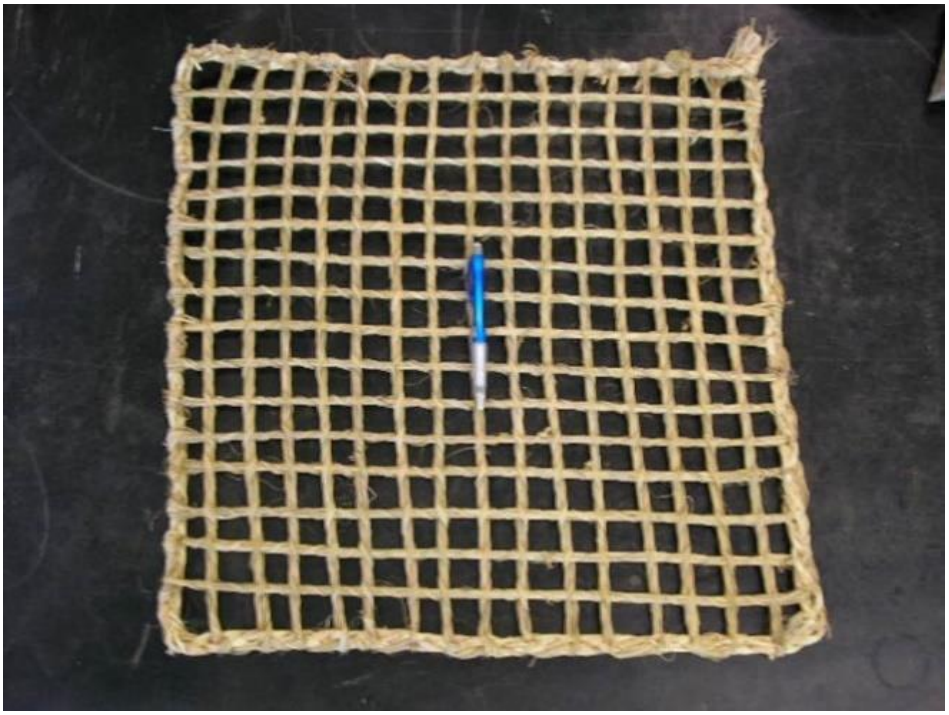

Figure 1. Buruti palm leaf biogeotextile mat

3. References to the research

The following research outputs (R1-R5) have been through a rigorous peer-review process and have been awarded peer-reviewed funding. Besides being cited by researchers in environmental engineering, the outputs are also cited in other disciplines (e.g. biology, hydrology, recycling, green technologies, and sustainable development issues), demonstrating that they are points of reference for further research beyond the original institution. Evidence of peer reviewed funding is reported below.

R1. Mitchell, D.J., Barton, A.P., Fullen, M.A., Hocking, T.J., Wu Bo Zhi & Zheng Yi. (2003). Field studies of the effects of jute geotextiles on runoff and erosion in Shropshire, UK. *Soil Use and Management*, 19(2), 182-184. https://www.doi.org/10.1079/SUM2002165.

R2. Bhattacharyya, R., Fullen, M.A., Davies, K. & Booth, C.A. (2010). Use of palm-mat geotextiles for rainsplash erosion control. Geomorphology, 119, 52-61. https://www.doi.org/10.1016/j.geomorph.2010.02.018.

R3. Egbujuoi, C.I., Fullen, M.A., Guerra, A.J.T. & Opara, A.I. (2018). Geochemical characterization of banana, Buruti palm, jute and coir fibres for use as biogeotextiles for erosion control. Journal of Environmental Engineering and Landscape Management, 26(3), 202-215. https://doi.org/10.3846/16486897.2017.1418365.

R4. Guerra, A.J.T., Bezerra J.F.R., Fullen, M.A., Mendonça, J.K.S. & Jorge, M.C.O. (2015). The effects of biological geotextiles on gully stabilization in São Luís, Brazil. Natural Hazards, 75, 2525-2636. https://www.doi.org/10.1007/s11069-014-1449-0. (UoA13 REF 2 Output).

R5. Guerra, A.J.T., Fullen, M.A., Jorge, M.C.O. & Bezerra, J.F.B. (2017). Slope processes, mass movements and soil erosion: A review. Pedosphere, 27(1), 27-41. https://www.doi.org/10.1016/S1002-0160(15)600.

Underpinning grant
Fullen, M.A. The BORASSUS Project. European Commission (International Cooperation with Developing Countries Scheme), Contract Number INCO-CT-2005-510745, GPB1,205,750 (converted from EUR). 2005 - 2010. Underpins R2, R4, R5.

4. Details of the impact

Impacts discussed below focus on the Community of Salina do Sacavém, which is in the suburbs (*favelas*) of the City of São Luís, the capital of Maranhão State, north-east Brazil. Researchers from the State University of Maranhão and the Federal University of Rio de Janeiro (both University partners in the BORASSUS Project) led the impact project, which has so far used the biogeotextiles mats [F1-F4] to substantially improve an area of previously severely gullied, eroded and degraded land. Prior to treatment, the area was poorly managed, leaving it as unprofitable waste-land and even a safety risk to visitors.

Over 16,000 Buruti palm leaf biogeotextile mats were installed across approximately 4,000m^2 area of severely sloping eroded land [C1]. This stabilised the ground and allowed gently sloping areas to be levelled as terraces (Figure 2). These bioengineering techniques, combined with a re-vegetation programme, led to the eventual stabilisation of over 50,000m^2 (5 hectares) of land [C1].

The initial treatment with the Buruti palm at Salina do Sacavém was undertaken in 2007, and over time re-vegetation was possible, which progressively improved and increased over time. This has led to various substantial impacts on the local area between August 2013 and December 2020, from environmental improvements [I1], to specific socio-economic benefits to the community [I2], to the area being used as a tool for a University-led environmental education programme [I3].

I1. Environmental benefits due to land stabilisation
Regular monitoring and field surveys since August 2013 highlight substantial environmental benefits in the area thanks to the environmental engineering and land stabilisation programme.

Identified effects on soil system dynamics included increased soil organic matter (and thus soil organic carbon) contents, decreased soil erosion, decreased soil erodibility and increased water infiltration into the stabilised soils. Related biotic effects included the development of permanent grass and woodland vegetation and increased floral and faunal biodiversity [C2]. The Head of Geography at the Federal University of Rio de Janeiro, stated that:

> "We have seen incredible environmental improvements on the stabilisation plantation land at Salina do Sacavém since 2013. These improvements are particularly evident in the stabilization of the gullies, improved soil physico-chemical properties and increases in both the number and biodiversity of species of flora and fauna" [C2].

These improvements highlight specifically how the biogeotextile mats have turned an area of unproductive wasteland into an area which now substantially benefits the local ecosystem.

I2. Benefits to the local community living near the stabilised land

Some 3500 families live within 500m of the Salina do Sacavém gullies. Their incomes are relatively low compared with local averages, with most working in the poorly paid service sector and many unemployed. Therefore, any opportunity to supplement incomes is particularly beneficial for these families.

In an interview in 2020, the President of the Association of Housewives of Salina do Sacavém highlighted the benefits she has observed resulting from the improved land stability. She cited an "end to landslides in the area" [C3], which were previously a significant danger in the area. She also indicated that an "end of accidents with children who use the gully as an entertainment area" [C3].

After treatment with the mats, the area was planted with over 500 Buruti palm trees, which were fully mature and producing fruit by 2013. The Research Professor on the project, from the State University of Maranhão, commented on the socio-economic benefits produced by the environmental improvements at Salina do Sacavém:

> "The community has enjoyed considerable benefits from the land stabilization project. These benefits include increased income from selling products from the Buruti trees, including artefacts produced from woven leaves and fruit products (such as juice and ice cream). The local people also use the crop of palm oil. As the agro-forestry plantation matures, these benefits have progressively increased. Between August 2013 - December 2020 we estimate that these products sold for about 12,000* Brazilian Reals" (*approximately GBP1700 as of 31st December 2020).

In a very poor area, the ability for the local community to subsidise low incomes is a significant benefit resulting from the project.

I3. Impacts on educational advancement in Maranhão State

As well as the benefits discussed above, the project has undertaken an education programme with local children, young people and adults over several years. The project was initiated in 2005, but has run ever since. Delivered by trained school teachers, the education programme provides classes at the local community centre, and conducts field visits for local people to study the stabilised area [C1]. The Research Professor on the project from the State University of Maranhão, who leads the education project, stated:

> "The program aimed to stimulate interest in environmental issues in the Community of Salina do Sacavém. The program established relationships between preservation, recovery and improving the quality of life. In addition, the program ensured on-going interaction between the community and the BORASSUS Project. The local people learnt a great deal about the recovery of degraded land using soil bioengineering techniques and the economic potential of biogeotextiles constructed using Buriti fibres."

He further identified that he has seen benefits from the programme in terms of "increased environmental awareness and the generally improved educational performance of local school students" [C1].

In 2020 the Research Professor and the President of the Association of Housewives discussed the impacts of the education programme on the local community. The outcomes of this discussion showed the significant importance of the programme in improving the environmental awareness of local people [C4]. The community leader particularly highlighted impacts on gender equality and that thanks to the programme "women have become much more involved in local environmental projects" [C4]. The continuing educational aspirations of the project are further evidenced by a webinar conducted on 14th August 2020 [C5].

Figure 2. Gully reclamation in progress in São Luís.

5. Sources to corroborate the impact

C1. Testimonial of the Research Professor from Maranhão State University on the socio-economic impacts of the research at the Salina do Sacavém site

C2. Testimonial of the Head of Geography (Federal University of Rio de Janeiro) on the environmental impacts of the research at the Salina do Sacavém site

C3. English-language translation of a testimonial from the President of the Association of Housewives of Salina do Sacavém.

C4. Transcript of discussion only available hand written in Portuguese. Contact details provided of Research Professor to corroborate.

C5. https://www.youtube.com/watch?v=LNgJ4oamDyA&t=1782s