The contribution of biogeotextiles to sustainable development and soil conservation in European countries: The BORASSUS Project

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1. Abstract

Field and laboratory experiments has shown that geotextile mats made from palm leaves are an effective, sustainable and economically-viable soil conservation method, with huge global potential. The EU-funded BORASSUS Project (2005-09; Contract Number INCO-CT-2005-510745) is evaluating the long-term effectiveness of biogeotextiles in controlling soil erosion and assessing their sustainability and economic viability. These experiments are in progress in 10 countries, both in the 'industrial north' (in Europe) and in the 'developing south' (Africa, South America and South-East Asia). This paper discusses the significance of geotextile palm mats in European countries (Belgium, Hungary, Lithuania and the UK).

Geotextile mats were effective in reducing splash erosion, runoff and soil erosion on arable sloping land in Shropshire, UK. The use of Borassus-mats on bare soil reduced soil splash height by ~31% and splash erosion by ~42%. The application of Borassus-mats as complete cover on bare soil reduced runoff by ~49% and soil erosion by ~75%. Borassus and Buriti mats as 1 m buffer strips reduced runoff by ~56 and 34%, respectively, and soil erosion by ~83 and 77%, respectively.

Results from selected types of vineyards in Hungary suggest that the geotextile mats are effective in reducing soil erosion, particularly erosive rainfall. The geotextiles mats are also helpful in maintaining moisture and temperature conditions in the surface soil at levels particularly conducive to the establishment and growth of young plants. Experiments in Lithuania show that geotextile mats are effective in encouraging the establishment and growth of natural vegetation, thereby reducing erosion on roadside slopes.

Simulated experiments in controlled laboratory conditions in Belgium suggest that palm-leaf geotextiles are effective in increasing infiltration rates and reducing interrill runoff and erosion rates on medium (i.e. 15%) and steep (i.e. 45%) slope gradients.

The effectiveness of geotextile mats when used as technical materials for the construction industry in ground strengthening was investigated. Generally, the tensile strength of the Buriti mats was approximately twice that of the Borassus mats. The tensile strength of the palm-leaf geotextile mats is influenced by the mat strip formation pattern.

Research and development activities of the BORASSUS Project have improved our knowledge on the effect of palm geotextile mats on the micro- and macro- soil environments and at larger scales through controlled laboratory and field experiments in diverse environments.

2. Introduction

Recent improvements have been made in soil conservation technology and over the last three decades significant advances have been made in our understanding of soil erosion mechanisms and rates under different environmental conditions. However, there have been few advances in developing innovative soil conservation techniques. One technique for soil conservation is geotextiles, which can create stable, non-eroding environments that provide the time necessary for vegetation to establish and grow. If constructed from indigenous materials, geotextiles can be effective, affordable and compatible with sustainable land management strategies (Booth *et al.,* 2005).

Despite synthetic geotextiles dominating the commercial market, geotextiles constructed from organic materials are highly effective in erosion control (Davies *et al.,* 2006) and vegetation establishment. Furthermore, they usually have 100% biodegradability and better adherence to the soil. Moreover, in developing regions, commercially-marketed materials are usually too expensive. Thus, the BORASSUS Project is assessing the feasibility of employing palm-leaf geotextile mats as a potential soil conservation technique. This contribution summarizes the aims and objectives of the BORASSUS Project and presents some preliminary (first 24 months) insights regarding the potential contribution of biogeotextiles to sustainable development in developed countries of the 'industrial north'.

3. The BORASSUS Project

Biogeotextiles can potentially advance soil erosion control in complex environmental situations, for instance on building and road construction sites, in gully stabilization and reclamation projects (Guerra *et al.,* 2005) and in coastal defence. However, as yet studies do not allow quantification of the effectiveness of palm-mat geotextiles in decreasing soil erosion rates by wind or water. Several work-packages in this Project address this issue through field measurements. However, a particular field site does not always offer the range of environmental conditions that can be found elsewhere in the region. One approach to establish the effectiveness of biogeotextiles for such conditions is through controlled laboratory experiments, during which erosive processes (rainfall, runoff and wind) are simulated for representative soil and slope conditions in the absence of, and with, biogeotextiles. Laboratory simulation studies are in progress in Belgium, China and South Africa, to validate field measurements in laboratory situations.

Biogeotextiles offer considerable potential to contribute to sustainable development and soil conservation. They efficiently and economically conserve soil, and preliminary evidence is presented that in developing countries, their use will promote sustainable and environmentally-friendly palm-agriculture, labour-intensive employment and earn hard currency.

The European Commission is funding the BORASSUS Project (Contract Number INCO-CT-2005-510745) for over three-years (2005-09) to investigate 'The Environmental and Socio-economic Contribution of Palm Geotextiles to Sustainable Development and Soil Conservation'. The BORASSUS team are scientifically testing the following four hypotheses:

1. Promotion of sustainable and environmentally-friendly palm agriculture will discourage deforestation and promote both reforestation and agroforestry. It will also offer a potentially profitable technique, which will provide financially-deprived farmers with supplementary income from palm geotextiles and thus contribute to poverty alleviation.
2. Construction of palm geotextiles will develop into a rural based labour-intensive industry, particularly encouraging the employment of socially-disadvantaged groups, such as women, disabled and elderly people. This will in turn contribute to the stabilization of rural populations, thus decreasing migration to urban areas.
3. Export of completed biogeotextiles to industrialized countries will earn hard currency for developing economies and promote development, based on the principles of fair trade.
4. Biogeotextiles efficiently and economically conserve soil and will be especially beneficial for complex engineering problems. Temporary application of biogeotextiles will allow sufficient time for plant communities to stabilize engineered slopes.

The Project consists of 13 work-packages using a team based in Europe (Belgium, Hungary, Lithuania and the UK), Africa (The Gambia and South Africa), South-East Asia (China, Thailand and Vietnam) and South America (Brazil) (Booth *et al.,* 2007). A report on the case studies in developing countries was presented in the 2007 ECOSUD-VI Conference in Coimbra, Portugal (Fullen *et al.*, 2007). This paper reviews the project insights into the potential contribution of biogeotextile technology to sustainable development in developed countries in the 'north'.

4. The contribution of biogeotextiles to sustainable development and soil conservation in European countries

Five case studies are reported which critically evaluate the potential contribution of biogeotextiles to agro-environmental development. These are distributed over several European countries (Belgium, Hungary, Lithuania and the UK). Then studies are integrated to distil general trends.

4.1 Case studies in the UK: Effects of palm-leaf geotextiles on run-off and erosion of arable soils in a temperate agricultural environment.

Geotextiles constructed from *Borassus aethiopum* (Black Rhun Palm of West Africa) and *Mauritia flexuosa* (Buriti Palm of South America) leaves have the potential to decrease soil erosion. In the UK, investigations are being conducted on the effectiveness of employing palm-mats to decrease soil erosion, by measuring runoff, soil loss and soil splash on humid temperate loamy sand soils.

Two sets (12 plots each) of experiments became operational at Hilton, east Shropshire, UK, on 22/01/2007, to study the effects of Borassus and Buriti mats on splash erosion. In either set, 6 plots were completely covered with mats, and the other 6 plots were bare. Soil splash was measured during 22/01/07-11/06/07 in each plot by collecting the splashed particles in a centrally positioned trap. Ten runoff plots (10 x 1 m on a 15^{o} slope) have been established at the same site, with duplicate treatments: (i) bare soil; (ii) grassed, (iii) bare soil with 1 m Borassus-mat buffer zones at the lower end of the plots, (iv) bare soil with 1 m Buriti-mat buffer zones at the lower end of the plots, and (v) completely covered with palm-mats. Runoff volume and sediment yield were measured after each substantial storm from 08/01/07-11/06/07.

Results indicate that total splash erosion in bare plots was 22.4 g/m^2 and mean splash height was 18.5 cm. The use of Borassus-mats on bare soil significantly reduced soil splash height by ~31% and splash erosion rates by ~42%. Total runoff from bare plots was 2.77 litres/m^2 and total sediment yield was 43.9 g/m^2. The application of Borassus-mats as complete cover on bare soil reduced runoff by ~49% and soil erosion by ~75%. Borassus and Buriti mats as 1 m buffer strips reduced runoff by ~56 and 34%, respectively, and soil erosion by ~83 and 77%, respectively. Buffer strips of Borassus mats are as effective as complete cover of the same mats in reducing soil loss. Thus, palm-mat (buffer strips) cover on vulnerable segments of the landscape is highly effective for soil and water conservation on these temperate loamy sand soils.

4.2 Case studies in Hungary: Investigations of the suitability of palm geotextiles in a sub-humid temperate climate.

In Year 2 of the BORASSUS Project the erosion research station built in Abaújszántó during Year 1 was perfected and measurements were carried out throughout the entire year. The experiments run on altogether 12 plots of 2 x 10 m, on three different land use types: young orchard, traditional vineyard and espalier vineyard. Four plots create a block for each land use type: two of them are bare surface and two are partly (in a 5 m wide strip) covered by geotextiles on their lower part. An automatic rain gauge is placed next to the plots to record important precipitation characteristics (rainfall amount, duration and intensity). Runoff and soil loss volume are measured after each rainfall event and samples are taken from the sediment each time. In parallel, soil moisture conditions at 20 cm depth and on the surface are measured by Ejelkamp soil moisture blocks and recorded every minute by a data logger. Thus, changes of soil moisture during and after precipitation events can be followed very sensitively. Analysing the data derived from these measurements (runoff, soil loss and soil moisture), the effectiveness of the applied geotextiles as a soil conservation technique are being evaluated as beneficial in three land use types.

Results suggest that the geotextile mats are effective tools against soil erosion, particularly during erosive rains. The geotextiles appear to have an important buffering effect on soil moisture and temperature changes in the surface soil, maintaining these parameters at levels particularly conducive to the establishment and growth of young plants.

4.3 Case studies in Lithuania: Use of palm geotextiles for stabilization of soil and sand dune erosion.

The suitability of the geotextile mats (Borassus and Buriti), as well as straw-coir and coir carpets, is being investigated using field experiments on road-side slopes in west-central Lithuania and sand dunes on the Baltic coast of Lithuania.

On the roadside experiment, runoff and soil losses were low due to prolonged dry conditions. Perennial grasses completely protected soil on the 21-25° slope. The highest soil losses were from the bare soil. Lower losses were from the slope with perennial grasses, which were sown in spring 2007. Application of Borassus and Buriti mats decreased soil losses by 60-65% and 40-51%, respectively. Borassus and Buriti mats significantly increased biomass of perennial grasses by 24 and 30%, respectively, thus increasing the protection against water erosion. Investigations are being continued in 2008 to evaluate changes in soil properties and plant growth under different geotextiles. The results of runoff and soil losses from the slopes with bare soil are being used for the development of a soil erosion model adapting the RUSLE2 at The Catholic University of Leuven. Geotextile mats were effective in encouraging the establishment and growth of natural vegetation, thereby reducing erosion on roadside slopes in Lithuania.

Dry weather and soil conditions prevented the emergence of seeds and plant growth on the sand dune of the Baltic coast. Planting of grasses and shrubs is more successful than sowing of cultivated or wild species on the sand dunes. Different species of grasses and shrubs successfully developed roots, even when planted in very dry meteorological and soil conditions.

4.4 Case studies in Belgium: Laboratory studies on the effectiveness of palm-leaf geotextiles in reducing rates of soil erosion by water.

In Year 1 of the BORASSUS Project, it was found that palm-leaf geotextiles are very effective in reducing total interrill soil loss and that this effectiveness decreases with increasing slope gradient. In Year 2, these findings have been extended by conducting more laboratory experiments on the effects of two palm-mat geotextiles and initial soil conditions on infiltration rates and interrill runoff and erosion rates on a medium and steep slope gradient under two rainfall intensities. The results from Year 2 indicate that palm-leaf geotextiles are effective in increasing infiltration rates and reducing interrill runoff and erosion rates on a medium (i.e. 15%) and a steep (i.e. 45%) slope gradient (Smets *et al.*, 2007). However, the effectiveness of geotextiles is higher on an initial fine tilth soil surface compared to a compacted soil surface. Preliminary results also indicate that palm-leaf geotextiles are effective in increasing the hydraulic roughness of the soil surface during concentrated flow and in reducing soil erosion rates by concentrated flow. In order to combine the results of interrill erosion and concentrated flow erosion, and to predict the effectiveness of geotextiles in reducing both interrill and rill erosion, an existing soil erosion model is adjusted and validated with field data from other BORASSUS partners. The procedure for calibrating and validating the soil erosion model started in Year 2 and in Year 3 of the BORASSUS Project, these validation procedures are being continued.

4.5 Case studies in the UK: Construction engineering: a manufacturing and geotechnical appraisal of vegetation fibre geotextiles for soil strengthening.

Geotextiles constructed from Borassus and Buriti palm leaves are currently being investigated for their effectiveness when used as geotechnical materials for the construction industry in ground strengthening. The study aims to identify and quantify the physical and technical characteristics of geotextiles which are manufactured from palm leaf fibres using 'low-tech', 'cottage-industry' manufacturing techniques and to correlate these properties with standard requirements for conventional high-specification technical ground engineering materials (geosynthetics). Grid mats manufactured in The Gambia and West Africa are currently under investigation for visual characterization and determination of tensile strength properties, in order to be used as engineering materials. Multiple and repeat measurements have been made of six Borassus and Buriti geomats individually at the initial stage in their life as soil reinforcements. The aperture area and the aperture width along the edge of each mat were measured. The aperture size of the Buriti mats is approximately twice that of Borassus mats. Whilst the distribution of aperture width along the edge of a mat was reasonably uniform for Buriti mats, with Borassus mats there was significant and random variations of aperture width and this could pose problems when trying to connect individual mats to make long reinforcements. Results from the preliminary tensile tests conducted on Borassus and Buriti mats using a Hounsfield tensiometer indicate that Borassus and Buriti palm-leaf geomats have a tensile strength in the range of 500-3000 N/m at ~10-15% failure strain. Generally, the tensile strength of the Buriti mats was approximately twice that of the Borassus mats. It has also been found that the tensile strength of the palm-leaf geotextile mats is influenced by the mat strip formation pattern (i.e. by the actual fabrication method). The second stage of the tensile testing of palm geomats is being conducted using Zwick Roehl equipment, which can accommodate large test specimens. This research will permit predictive quantification of the durability characteristics (i.e. the change in tensile strength with time) of palm-leaf geotextiles buried within different types of ground.

5. Discussion

Preliminary project results are very positive; with strong field and laboratory evidence indicating that biogeotextiles can have several beneficial effects, which were repeated in field and controlled conditions in several European countries. Effects also appear consistent between selected land use systems (arable land, orchards, sand dunes and controlled laboratory conditions). Some positive effects of geotextile mats include:

1. The geotextile mats were effective in reducing splash erosion, runoff and soil erosion on arable sloping land in Shropshire, UK.
2. Results from selected types of vineyards in Hungary suggest that the geotextile mats are effective in reducing soil erosion, particularly during intense erosive rains. The geotextile mats are also helpful in maintaining moisture and temperature conditions in the surface soil at levels particularly conducive to the establishment and growth of young plants. Geotextile mats were effective in encouraging the establishment and growth of natural vegetation, thereby reducing erosion on roadside slopes in Lithuania.
3. Simulated experiments in controlled conditions in Belgium suggest that palm-leaf geotextiles are effective in increasing infiltration rates and reducing interrill runoff and erosion rates on medium (i.e. 15%) and steep (i.e. 45%) slope gradients.
4. The effectiveness of geotextile mats when used as technical materials for the construction industry in ground strengthening is being investigated. Generally, the tensile strength of the Buriti mats was approximately twice that of the Borassus mats. The tensile strength of the palm-leaf geotextile mats is influenced by the mat strip formation pattern.
5. Research and development activities of the Project have improved our knowledge on the effect of palm geotextile mats on the micro- and macro- soil environments and at larger scale through controlled laboratory and field experiments in diverse environments.

Further information can be obtained from the BORASSUS Project website (www.borassus-project.net). Full Project publications can be accessed on the University of Wolverhampton WIRE free-access web site: http://wlv.openrepository.com/wlv/

6. Conclusions

Investigations indicate that the biogeotextile mats effectively decreased soil and water erosion. They were found effective in reducing soil and water losses in varied land use types (arable land, orchards and engineered roadside slopes). They contributed favourably to the growth of both crops and natural vegetation. Biogeotextile mats are biodegradable, providing organic content matter and nutrients to the soil and their permeability makes them suitable for use with cohesive soils. There are no high-energy production procedures in the manufacturing process and they may provide a cost-effective method of conserving soil in developing countries, where farming techniques are scaled to low levels of disposable income. They are also applicable in soil and water conservation projects in European agro-environments.

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