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# THE EFFECTS OF BIOGEOTEXTILES ON THE STABILIZATION OF ROADSIDE SLOPES IN LITHUANIA

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**Abstract.** Biogeotextiles constructed from the leaves of *Borassus aethiopum* and *Mauritia flexuosa* are investigated at the Kaltinėnai Research Station of the Lithuanian Institute of Agriculture, which is participating in the EU-funded BORASSUS Project. Biogeotextiles are potentially excellent biodegradable and environmentally-friendly materials useful for soil conservation. Field studies on a steep (21–25°) roadside slope in Lithuania suggest biogeotextile mats are an effective and sustainable soil conservation technique. Biogeotextiles have a potential as a biotechnical soil conservation method for slope stabilization and protection from water erosion on steep industrial slopes and may be integrated with the use of perennial grasses to optimize protection from water erosion. The investigations demonstrated that a cover of Borassus and Buriti mats improved the germination and growth of sown perennial grasses. The biomass of perennial grasses increased by 52.0–63.4% under cover of Borassus mats and by 18.6–28.2% under cover of Buriti mats. Over 2 years, the biogeotextiles (Borassus and Buruti, respectively) decreased soil losses from bare fallow soil by 90.8% and 81.5% and from plots covered by perennial grasses by 87.9% and 79.0%, respectively.

**Keywords:** soil erosion, roadside slopes, vegetation cover, biogeotextiles.

## 1. Introduction

Soil erosion is one of the world's most serious environmental problems, causing extensive loss of cultivated and potentially productive soil and crop yields (Fullen, Catt 2004; Morgan 1995). Water erosion is the main soil degradation factor in agricultural areas, which endangers 56% of the world's available arable land and has already eliminated an estimated 430 mln ha from agricultural production, or 30% of the total available arable land (United Nations Environment Programme 2002). Major causes of water and wind erosion include deforestation, overgrazing and mismanagement of arable land. By removing vegetation cover the erosion-resisting capacity of the soil becomes disturbed. The kinetic energy of raindrop splash increases, resulting in an increased soil detachment. Hydraulic surface flow increases with the lack of vegetation cover, which also increases the soil susceptibility to erosion, by reducing cohesion and shear strength (Rickson, 2001). About 17% of Lithuania's agricultural land is eroded, increasing to 43–58% in hilly regions. Water and wind erosion occurs mostly on arable soils and wind erosion occurs on the Baltic coast (Jankauskas *et al.* 2004). There are many inexpensive potential soil conservation measures on arable soils in Lithuania (Jankauskas, Fullen 2006; Jankauskas *et al.* 2004, 2008). Special attention is required to industrial slopes, where plant cover is often destroyed by machinery and soil truncation may occur. Special difficulties arise due to exposure of deeper soils deficient in soil organic matter, which are thus especially vulnerable to water and wind erosion. Geotextiles are one of the methods suitable for soil conservation on such engineered industrial slopes.

Geotextiles constructed from indigenous tropical/subtropical leaves has potential as a biotechnical soil conservation method. The results of investigations indicate geotextiles constructed from palm leaves effectively reduced soil erosion. If harvested correctly, these resources

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are highly sustainable and readily available. They are biodegradable, providing organic content matter to stabilize the soil and their permeability makes them suitable for use on cohesive soils (Booth *et al.* 2007; Fullen *et al.* 2006). Geotextiles are used for many engineering applications to improve soil properties. On steep erodible slopes, where the vegetation growth is limited by erosive forces of rain and runoff, geotextiles can serve as a temporary replacement of vegetative cover (Smets *et al.* 2007).

Geotextiles have contributed to the erosion control industry for over 50 years (Dayte, Gore 1994; Mitchell *et al.* 2003) and are mainly used in civil engineering projects, such as dam retaining walls and for road and reservoir slope stabilization (Davies *et al.* 2006). Despite synthetic geotextiles dominating the commercial market, geotextiles constructed from organic materials are highly effective in erosion control and vegetation establishment (Davies *et al.* 2006; Ogobe *et al.* 1998). Palm leaf geotextiles could be an effective soil conservation method with enormous global potential. They can be installed on steep erodible slopes, as a replacement or supplement to vegetative cover, to reduce the erosive forces of rain and runoff (Smets *et al.* 2007). The performance of geotextiles on road pavement structures and in protection of roads from transport load stresses has been investigated in Lithuania (Vaitkus *et al.* 2007).

## 2. Materials and methods

The European Commission is funding the BORASSUS Project (Contract No. INCO-CT-2005-510745) for over 3.5 years (2005–2009) to investigate *"The Environmental and Socio-economic Contribution of Palm Geotextiles to Sustainable Development and Soil Conservation"*. Project objectives are deliverable to both "developing" and "industrialized" countries. The BORASSUS Team, based in 10 countries in Europe, Africa, South-East Asia and South America, are scientifically testing four hypotheses, one of which is: biogeotextiles efficiently and economically conserve soil. Palm geotextiles will be especially beneficial for complex engineering problems, particularly in the building and road construction industries and coastal defence. Temporary application of geotextiles will allow sufficient time for plant communities to stabilize engineered slopes. Palm geotextiles will decrease water evaporation, increase topsoil moisture, improve conditions for plant growth and they will be refuge for wildlife and soil fauna. Furthermore, they are environmentally-friendly, because of their excellent biodegradability. To test this hypothesis, field experiments were conducted using runoff plots (width 2 m and length 7.5–6.2 m) on a steep (21–25°) roadside slope.

The suitability of two types of mats for stabilizing of soil erosion processes on steep industrial slopes (roadside slopes) are being investigated in the Šilalė District of Lithuania (55°33'N, 22°22'E). These included Borassus mats, constructed from *Borassus aethiopum* (Black Rhun palm) leaves in The Gambia, and Buriti mats, constructed from *Mauritia flexuosa* (Buriti Palm) in Brazil. Manufactured straw-coir and coir carpets were also investigated for comparison.

Borassus mats, coir carpet and straw-coir carpet were used in the 1$^{st}$ set of field experiments in May 2006 (Fig. 1, 2$^{nd}$ replication). A multi-species mixture of perennial grasses (Pg) consisted of 20% each of: orchard-grass (*Dactylis glomerata* L.), red fescue (*Festuca rubra* L.), Kentucky bluegrass (*Poa pratensis* L.), white clover (*Trifolium repens* L.) and alfalfa (*Medicago sativa* L.). The mixture was sown into topsoil (0–5 cm). Randomly located treatments were: cover by straw-coir carpet (Pg+straw), Borassus mats (Pg+Borassus), perennial grass control without geotextile cover (Pg) and coir carpet (Pg+coir). Weather conditions were very dry in the following three months. The monthly precipitation in Ju and Jul 2006 was lower than the long-term average (1960–2004) by 3.6 and 4 times, respectively. The 2$^{nd}$ set of field experiments was initiated at the end of the long dry period, on 4 Aug, 2006 (Fig. 1, 3$^{rd}$ and 4$^{th}$ replications). The design of investigations was changed and included Buriti mats instead of coir carpet. The specified Pg mixture was sown before covering the soil with selected geotextiles. The 3$^{rd}$ set of field experiments was carried out in early spring, 14 Apr, 2007 (Fig. 1, 1$^{st}$ replication). In addition to four treatments, as in Aug 2006, three additional plots (Fig. 1, bare soil) were constructed on bare soil: control without geotextile cover and covered by Borassus and Buriti mats with collectors for runoff and sediment (Fig. 2). Dry conditions in Apr (only 35.9% of precipitation compared with the long-term average) prolonged the germination of sown perennial grasses. Weather conditions improved in May: total precipitation in May was slightly above the

| Bare soil | | | 1$^{st}$ replication | | | | 2$^{nd}$ replication | | | | 3$^{rd}$ replication | | | | 4$^{th}$ replication | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| IIIa | Ia | IIa | I | III | II | IV | IV | II | I | III | II | III | IV | I | III | II | I | IV |

**Fig. 1.** The scheme of field experiment on the roadside slope (21–25°), Apr 2007: 1–19 numbers of the plots; I–IV numbers of treatments under perennial grasses; Ia–IIIa numbers of treatments with bare soil

**Fig. 2.** 3rd set of field experiments, Apr 2007

long-term average, but high air temperatures caused high evaporation rates and, therefore, there was a moisture deficit from late spring to early summer (i.e. mid-June).

Soil sampling for soil moisture was determined by drying soil samples in laboratory in 2006. Soil samples were collected every 10 days from the upper part of the slope (3 individual samples) and from the basal slope (3 individual samples). Soil moisture was determined using a soil moisture meter type HH2 in 2007. Measurements (6 individual measurements from each plot) were performed every 10 days on the topsoil (0–6 cm).

Data were analysed using the computer programs ANOVA, STAT and SPLIT-PLOT from the package SELKCIJA and IRRISTAT (Tarakanovas, Raudonius 2003).

### 3. Results and discussion

Soil physical properties on the roadside slope are different in the topsoil (0–10 cm), and a deeper (11–20 cm) soil. The road cutting soil represents the top of a mechanically-truncated soil profile and hence external topsoil was added to improve plant growth. Particle size analysis (Table 1) shows topsoil to be sandy loam and the deeper soil – a loamy sand. Both these soil textures are light, having high water permeability, but are erodible (Morgan, 1995).

**Table 1.** Soil particle size analysis* on the roadside slope

| Soil layers, cm | Washing** losses, % | Fractions, %* | | |
|---|---|---|---|---|
| | | Sand 1.0–0.05 mm | Silt 0.05–0.001 mm | Clay < 0.001 mm |
| 0–10 | 6.5 | 67.6 | 12.7 | 13.2 |
| 11–20 | 6.9 | 79.0 | 7.0 | 7.0 |

Note:
* – particle size analysis by the Kachinskij method (Мичманова, Долгов 1966), mean of 5 soil samples;
** – dissolution losses in HCl, which removes soluble soil matter, mostly $CaCO_3$.

Mean soil chemical characteristics on the roadside slope (Table 2) show alkaline properties, base-saturation was > 99% and there was no detectable available Al. As the engineered soil was truncated, it had a low soil organic matter content compared with the applied topsoil, which was rich in available P and moderately rich in K.

**Table 2.** Mean* chemical soil properties on roadside slope before field experiments

| Soil layers, cm | $pH_{KCl}$ | Available Al | Available P | Available K | Organic matter, g/kg |
|---|---|---|---|---|---|
| | | mg/kg | | | |
| 0–10 | 7.7 | 0 | 66.9 | 84.7 | 24.5 |
| 11–20 | 8.1 | 0 | 32.3 | 56.4 | 8.0 |

Note: * – 50 individual samples

Dry weather conditions determined low soil moisture (2.8–5.2%) and unfavourable conditions for the germination and growth of perennial grasses in May–June and the 1st 10 days (decade) of Aug 2006. Increased soil moisture in Aug corresponds to intense rains in the 2nd decade of Aug. Therefore, quite favourable air and soil moisture (11.0–14.1%) conditions for germination of perennial grasses were present in Aug 2006. Soil moisture was 4.52% before enlarging the roadside field experiment on 4 Aug 2006. The lowest mean soil moisture (12.04%) was on the plots not covered by geotextiles during the moist period from 14 Aug – 15 Sep. Under Borassus and Buriti mats and straw-coir carpet mean soil moisture contents were 15.10%, 13.28% and 13.21%, respectively.

Dry weather conditions in Apr 2007 determined a low soil moisture (only 3.7–5.0%) for the germination of perennial grass in early spring 2007. At the end of the 1st decade of May conditions for germination became more favourable (soil moisture varied within 18.6–20.0%), but in mid-May there were 13 hot days without precipitation, which desiccated plants in the early stages of germination.

According to the results from field experiments conducted in Aug 2006, perennial grasses under the Borassus and Buriti geotextile mats had higher productivity. Alfalfa and orchard grass prevailed among the sown grasses. There was evidence that cover of Borassus and Buriti mats increased soil moisture storage. Coir and straw-coir carpets also decreased the evaporation of soil moisture, but they impeded normal plant growth. The sprouts of grasses unsuccessfully tried to penetrate the carpet and they even raised the carpet above the soil surface.

Slightly higher soil moisture was evident under the cover of Borassus and Buriti mats in Apr–May and especially in Aug–Oct 2007, but soil moisture contents were fairly uniform, irrespective of treatment, from the 2nd decade of Ju to the last decade of Aug. Soil moisture conditions influenced the germination and productivity of newly sown grasses, and growth of perennial grasses sown in 2006 (Table 3). Density of sown cereals and leguminous grasses was evidently higher under the cover of Borassus and Buriti mats, compared with uncovered soil, and also

**Table 3.** Density and productivity of grasses under different soil covers on the road-side slope in 2007

| Treatments | Productivity, dry biomass (Mg/ha), (Σ of 3 harvests) | | | Density of sown grasses in 1 $m^2$ | |
|---|---|---|---|---|---|
| | F.e.*, May 2006 | F.e.*, Aug 2006 | F.e.*, Apr 2007 | Cereals | Legumes |
| Pg (no mat cover) | 5.20 | 4.56 | 3.47 | 575 | 375 |
| Pg+Borassus | 6.69 | 6.93 | 5.67 | 1100 | 650 |
| Pg+Buriti | 4.87** | 5.41 | 4.45 | 800 | 475 |
| Pg+straw-coir | 5.40 | 4.45 | 3.54 | 725 | 350 |
| $LSD_{05}$ | 0.319 | 0.442 | 0.222 | 22.5 | 27.0 |

Note:
* – F.e. means "field experiment carried out";
** – this specific result is under coir carpet cover. Pg means "a multi-species mixture of perennial grasses".

compared with the straw-coir cover. Soil moisture and density of grasses influenced a significantly higher productivity under cover of Borassus and Buriti mats.

An evaluation of erosion rates is an important component of these investigations. There was no runoff or soil loss during the dry summer period in 2006. The 1st runoff and soil loss was after the 11.7 mm rainfall event on 14 Aug, 2006. Erosion was not high, even from the control plots, because sown perennial grasses had germinated and covered the slope surface. There were 11 runoff events (only 6 of them contained sediment) during Aug–Nov 2006. The summarized data indicate higher soil losses from the field experiment laid out in May 2006 compared with data from the field experiment laid out in Aug 2006 (Table 4), because the scant plant cover was under the 1st set of field experiments in May 2006. Most runoff was from the plots covered by straw-coir carpet, but these experienced least soil losses. The explanation is that a part of water flows down from the surface of the straw-coir carpet and decreased water available for soil erosion processes. The largest soil losses (0.26 $Mg/ha^{-1}$) from field experiments, conducted in Aug 2006, were from the control plots not covered by geotextiles. Biogeotextiles decreased soil losses by 19.8 and 15.4%, respectively, from the plots covered by Borassus and Buriti mats.

**Table 4.** The losses of dry soil under different treatments from the roadside experiment (16 Aug –11 Sep, 2006)

| Field experiment | | | |
|---|---|---|---|
| May 2006 | | Aug 2006 | |
| Treatments | Soil loss*, Mg/ha | Treatments | Soil loss*, Mg/ha |
| Pg | 1.730 | Pg | 0.260 |
| Pg+Borassus | 0.740 | Pg+Borassus | 0.210 |
| Pg+coir | 1.070 | Pg+Buriti | 0.220 |
| Pg+straw | 0.580 | Pg+straw | 0.160 |
| $LSD_{05}$ | 0.321 | | 0.038 |

* – 6 events caused water+sediment loss

The first soil erosion loss from the field experiment established in Apr 2007 was from the 18.2 mm rainfall of 9 May, 2007. The damage was not high even from the control (bare) plots, because most precipitation penetrated the dry permeable soil. Highest soil losses (0.68–0.2 Mg/ha) were from plots not covered with biogeotextiles. Young and weak sprouts of perennial grasses were unable to prevent runoff from uncovered plots. Least soil losses were from the plot covered by straw-coir carpet, because some runoff

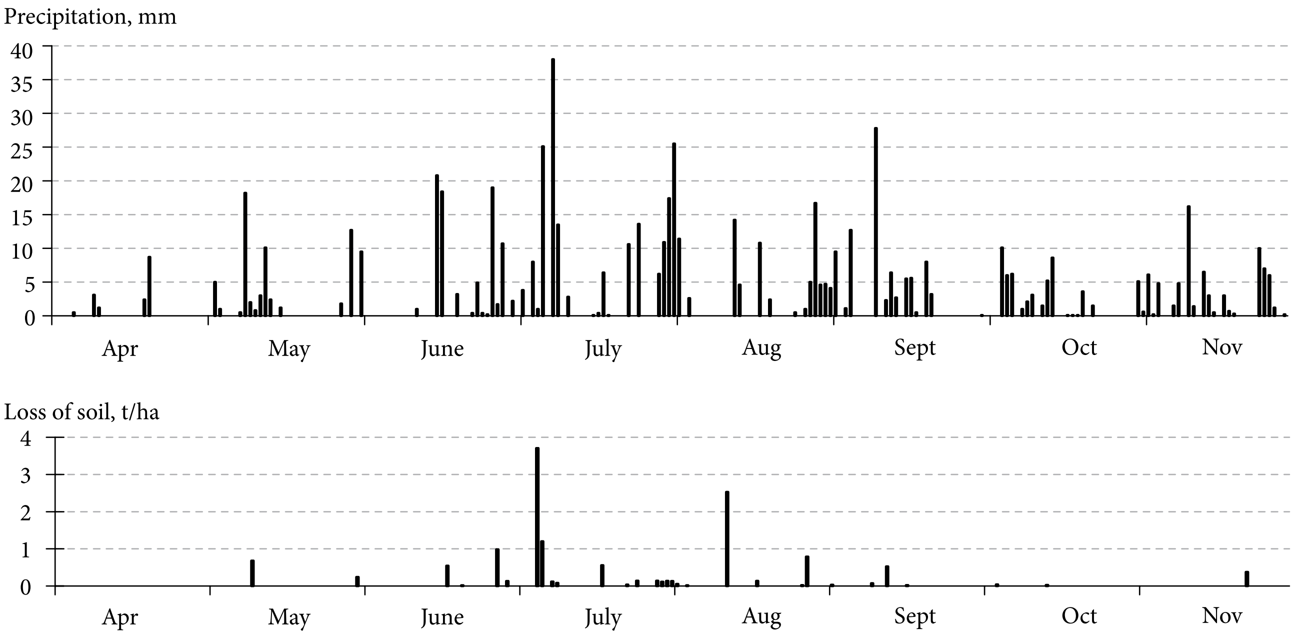


**Fig. 3.** Daily precipitation during the 2007 vegetative period and soil losses from the bare fallow roadside slope

was from the carpet surface. Borassus mats stabilized the runoff more effectively than Buriti mats. Later there were 30 other events with soil losses until 1 Dec, 2007, but there was no evident relationship between daily precipitation and soil losses (correlation coefficients: linear $R^2 = 0.002$, power $R^2 = 0.178$, modified power $R^2 = 0.182$) (Fig. 3).

The highest soil loss from the uncovered bare fallow plot (3.7 Mg/ha) occurred on 04 Jul, 2007, after a short very intense shower of only 8.0 mm. The contrary case was on 7 Jul, 2007, when after 38 mm daily rainfall, there was only 0.12 Mg/ha of soil loss (Fig. 4). Erosion rates were: 13.6 Mg/ha from the plot without biogeotextile cover, 1.3 Mg/ha from Borassus cover and 2.5 Mg/ha from Buriti cover (Fig. 4). Cover of Borassus mats deceased soil losses from bare fallow soil by 90.8% and cover of Buriti mats by 82.5%. Quite scant perennial grasses on plots not covered by geotextiles limited the protection from water erosion, where 1.41 Mg/ha of soil was lost, compared with plots covered by different geotextiles, where losses were only 0.15–0.31 Mg/ha. These results accord with the hypothesis that geotextiles constructed from organic materials are highly effective in erosion control and vegetation establishment (Davies *et al.* 2006).

## 4. Conclusions

The results from two years (2006, 2007) of field investigations indicate biogeotextiles constructed from palm leaves effectively stored soil moisture on a steep (21–25°) roadside industrial slope. Improved soil moisture conditions encouraged better germination, density and productivity of perennial grasses and thus effectively conserved soil. Cover of Borassus and Buriti mats increased the density of legumes and cereals by 73.3–91.3% and 26.7–39.1%, respectively. Consequently, the biomass of perennial grasses increased by 52.0–63.4% under cover of Borassus mats and by 18.6–28.2% under cover of Buriti mats. Borassus and Buriti mats reduced water erosion rates from bare fallow soil by 90.8% and 81.5%, respectively, and from plots covered by perennial grasses by 87.9% and 79.0%, respectively. Coir and straw-coir carpets also decreased the evaporation of soil moisture, but they impeded normal plant growth.

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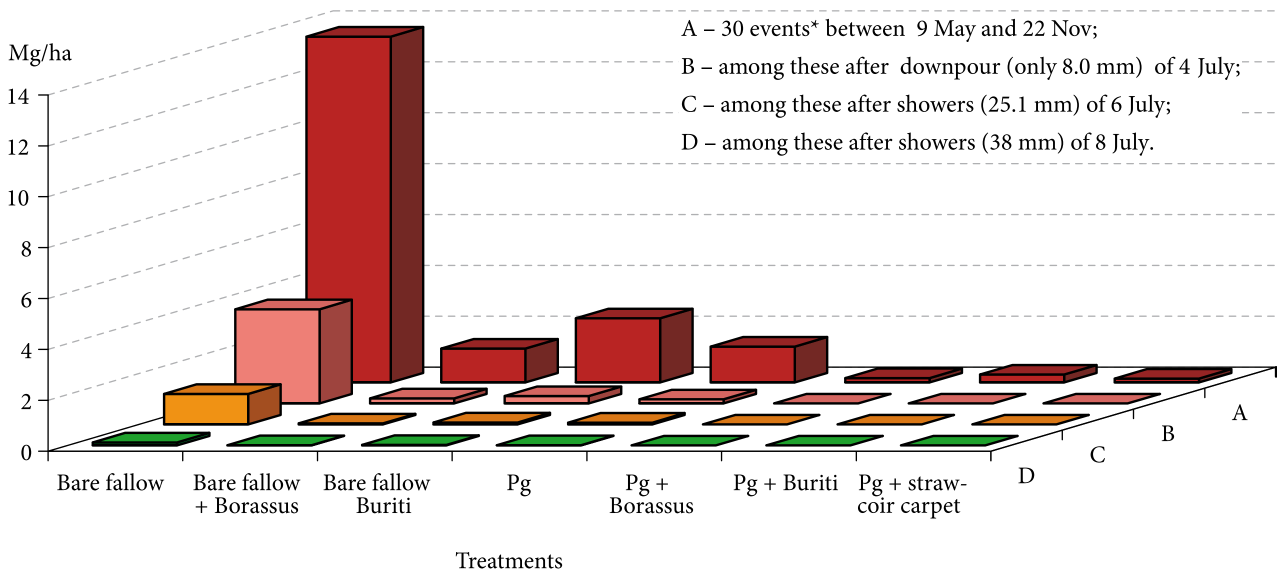


**Fig. 4.** Soil losses May–Nov 2007 from 6–7 m length plots on the 23–25° roadside slope; * – days with runoff and soil loss

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