A field experiment on the use of biogeotextiles for the conservation of sand-dunes of the Baltic coast in Lithuania

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Abstract

Extreme damage was caused by wave and wind erosion on sand dunes on the Baltic coast near Palanga in Lithuania. Waves breached a wide 'corridor' or 'blowout' through the coastal sand dune. A progressively widening breached blowout developed. There was a need to protect boundaries (walls) of the blowout from deflation and to encourage sand-dune accretion. The field experiment was performed to establish vegetation on the 'walls' and base of the blowout to stabilize the feature and stimulate sand-dune accretion. The hypothesis was tested that biogeotextiles could act as complementary measures for possible re-vegetation and temporary prevention of deflation.

The application of biogeotextile mats, constructed from the palm-leaves of *Borassus aethiopum* (Borassus) and *Mauritia flexuosa* (Buriti), has been investigated in field experiments on coastal sand dunes. Biogeotextiles effectively stored soil moisture during dry summer periods. Covering sand-dune slopes with biogeotextiles and planting local species of grasses, shrubs and trees enabled the stabilization of a breached 'corridor' through the sand-dune and a mean sand-dune accretion rate of 24.7 cm per year, over three years. The results of investigations show biogeotextile cover enabled stabilization and restoration of vulnerable ecosystems on the Baltic coastal sand-dune.

Geotextile cover prevented further deflation of the blowout; biogeotextile cover increased moisture storage and encouraged vegetation growth (planted shrubs and grasses); and biogeotextiles improved microclimatic and moisture conditions for the development of planted sprouts of plants communities. In turn, these changes encouraged rapid sand accretion and 'growth' of the basal sand dune. These processes contributed to the restoration of the breached sand-dune, sand accumulation and improved ecosystem functioning.

Keywords: biological geotextiles, coastal sand-dunes, landscape evolution, soil moisture, vegetation cover, wind erosion

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Introduction

Soil degradation by erosion is one of the world's most serious environmental problems, causing extensive loss of cultivated and potentially productive soil and crop yields (Fullen, M.A. and Catt, J.A. 2004; Morgan, R.P.C. 2006; Kertész, Á. 2009). It has been estimated that some 6,000 million tonnes of soil per year have been washed off the croplands of India (Fullen, M.A. and Catt, J.A. 2004). During the last 50 years, erosion has increased about 30-fold on some soils in Russia and crop production on these soils has decreased by 50–60% (Andronikov, S. 2000). The erosion-resisting capacity of the soil is disturbed by removing vegetation cover. 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. There are many inexpensive potential soil conservation measures on arable soils in Lithuania (Jankauskas, B. *et al*. 2004, 2008a; Mazvila, J. *et al.* 2010). Vegetation cover is often undervalued in terms of its control over landscape incision (Howard, A. D. 1997; Poesen, J. *et al*., 2003). Conservation agriculture is a very successful method for retaining soil moisture and for decreasing the sediment load of surface waters. Adequate soil moisture can encourage both soil flora and fauna (Madarász, B. *et al*. 2011).

The drift sands of the Holocene are an important component of the European Sand Belt. They have been described by several authors (Högbom, I. 1923; Manikowska, B. 1995; Seppälä, M. 1995; Zeeberg, J.J. 1998; Göllnitz, D. 1999; Mangerud, J. *et al*. 1999; Bitinas, A. 2004; Koster, E.A. 2005, 2009; Satkunas, J. 2009). The youngest cover sands contain little silt and clay (Hoek, W. Z. 1997), which makes them susceptible to wind erosion.

The problem of coastal erosion is becoming increasingly evident on the south-east Baltic coast. Its fine-textured sandy beaches were heavy affected by storms in the late 20th century. Extreme damage, caused by wave and wind erosion on dunes, was exacerbated by anthropogenic activities. Waves breached a wide blowout through the coastal sand dune. Damage was even more serious after the stormy winter of 2001–2002: the coastal strip south of the town of Palanga was heavy eroded and the loss of sand exceeded 20,000 m^3 (12.5 m^3 m^{-1}) (Zilinskas, G. 2005). A ~30 m wide 'blowout' through the coastal sand-dune near Nemirseta was breached by pressure of natural (intense storm activity) and anthropogenic (footpath) activities and subsequently progressively widened. Therefore, there was a need to protect boundaries (walls) of this blowout from deflation and to encourage sand-dune accretion. The dynamics of the dunes preconditions the distribution of plant communities in aeolian systems (Morkunaite, R.–Cesnulevicius, A. 2005). However, we attempted to establish vegetation on the 'walls' and on the bottom of the blowout to stabilize the feature and stimulate sand-dune accretion. The hypothesis was tested that biogeotextiles could act as complementary measures for possible re-vegetation and for temporary prevention of deflation.

Geotextiles are potentially excellent biodegradable and environmentally-friendly materials useful for soil conservation. The results obtained under UK rainfall intensities suggest that palm-mat application is highly effective for soil conservation. Water erosion rates equated to 0.45 Mg ha^{-1} from bare soil, 0.09 Mg ha^{-1} from grassed plots and 0.17 Mg ha^{-1} from both covered and buffer zone plots (Davies, K. *et al*. 2006). Geotextiles from leaves of the Lala palm (*Hyphaene coriacea*) reduced sediment yield from tailing dam slopes in South Africa by 55% (Bühmann, C. *et al*. 2010). The application of geotextile mats, constructed from the palm leaves of *Borassus aethiopum* (Borassus) and *Mauritia flexuosa* (Buriti), has been investigated at Kaltinenai Research Station of the Lithuanian Research Centre of Agriculture and Forestry. The geotextiles (Borassus and Buruti, respectively) decreased soil losses from bare fallow soil by 91% and 82% and from plots covered by perennial grasses by 88% and 79%, respectively. This illustrates that geotextiles have considerable 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 (Jankauskas, B. *et al*. 2008b). Thus, we assessed the rehabilitation of degraded area on a breached sand-dune in the Pajurio Regional Park on the Baltic coast near Nemirseta (Lithuania) and the results of these investigations are presented.

It is postulated that biological geotextiles could act as a complementary measure for temporary prevention of deflation and to temporarily increase moisture storage, creating better conditions for re-vegetation. Of course, widespread adoption or dune stabilization measures are neither feasible nor desirable, considering the dynamic nature of the dune pedo-environment. However, carefully considered and targeted stabilization may make a balanced contribution to specific coastal sites.

Area descriptions, materials and methods

The European Commission funded the BORASSUS Project (Contract Number INCO-CT-2005-510745) for over three-years (2005–2009) to investigate 'The Environmental and Socio-economic Contribution of Palm Geotextiles to Sustainable Development and Soil Conservation.' Project objectives were deliverable to both 'developing' and 'industrialized' countries. The BORASSUS team was based in 10 countries (in Europe, Africa, South East Asia and South America) and scientifically tested four hypotheses, one of which is: palm-mat geotextiles efficiently conserve soil. To test this hypothesis, field experiments were conducted on the sand-dunes of the Baltic coast. The duration of the field experiment was three years.

Meteorological conditions during the three year project (2006–2008) are demonstrated in *Figure 1*. The mean monthly precipitation and temperatures present moisture and temperature conditions compared with the long-term mean. The highest monthly temperature was 20.1 °C in July 2006 and the lowest (-7.7 °C) in January 2006. Unusually high precipitation (170 mm) and mean air temperatures (1.9 °C) occurred in January 2007. Unusually high precipitation in July 2007 influenced lower temperatures compared with June and August. The winter of 2007–2008 was unusually warm, when average temperatures in December, January and February were ≥0 °C. Very dry periods in April and May occurred during each year of investigations. These conditions were unfavourable for the germination of seeds of perennial grasses sown in early spring.

Field experiments were conducted on the slope of a breached sand dune in Pajurio Regional Park on the Baltic coast, near Nemirseta (55°52'22''N; 21°03'25'' E). The soil is a Hapli-Calcaric Arenosol (ARc-ha) (Mazvila, J. *et al*. 2006). Particle size analysis shows that most material is sand (1.0–0.05 mm: 96.1%). The silt fraction is only 1.7 % and clay fraction 0.4% (*Table 1*). These data accord with general observations that young cover sands contain little silt and clay (e.g. Hoek, W.Z. 1997).

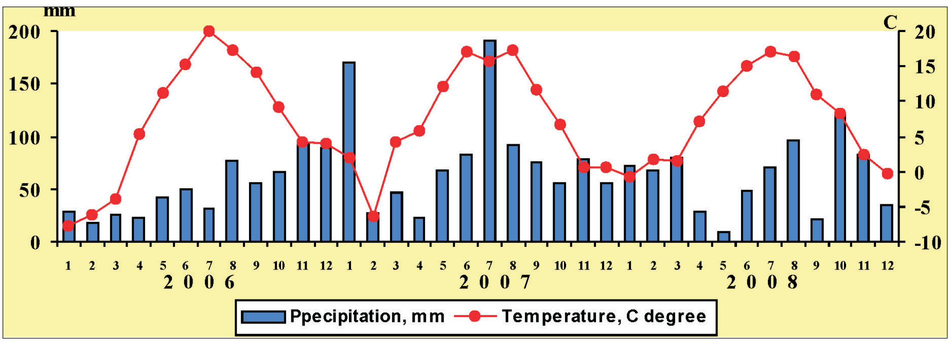

Fig. 1. Monthly precipitation and temperatures during the project (2006–2008)

Table 1. Particle size analysis of dune sands (fractions in % by weight)*

Soil depth, cm	Fractions, mm					
	1.0–0.25	0.25–0.05	0.05–0.01	0.01–0.005	0.005–0.001	<0.001
	Sand		Silt			Clay
0–20	8.8	88.1	0.4	0.4	0.9	0.4
	Mean sand = 96.1%		Mean silt = 1.7%			Mean clay = 0.4%

*Particle size analysis by the Kachinskiy method, n = 12 samples.

The dune sand had pH (KCl) 6.8, base saturation 92.4–92.5% and 0 available Al. The amount of organic matter (0.4 g kg^{-1}) and available K (15.8–24.1 mg kg^{-1}) accords with sandy soil properties. High concentrations of available P (168.2–185.3 mg kg^{-1}) can be attributed to periodic marine inundation.

For historical reasons, soil analytical techniques were mainly Russian procedures (Jankauskas, B. and Fullen, M.A. 2002). Soil textural classes were determined by the N. Kacinskij method (Michmanova, A.I. and Dolgov, S.I. 1966; Motuzas, A.J. *et al.* 1996), which is commonly used in Eastern Europe.

Soil reaction (pH_{KCl}) was determined in 1M KCl soil sample extracts using a calibrated digital pH meter. Hydrolytic acidity (H), which was used for calculation of base saturation, was determined in 1M CH_3COONa on soil sample extracts (ratio sample: extract, 1:25 for mineral soil) by titrating with 1M NaOH (Askinazi, D.L. 1975).

Exchangeable bases (*S*) and base saturation (*V*) were determined by the Kappen-Hilkovic method, which is based on hot titration of 0.1M HCl and soil sample filtrate (ratio sample:extract 1:5) with 0.1 M NaOH (Askinazi, D.L. 1975). Ca^{++}, Mg^{++}, K^+, Na^+ and NH_4^+ concentrations (meq kg^{-1}) were determined on filtrates and base saturation (*V*) calculated using the formula:

$$V = [S : (S + H)] \times 100,$$

where V = % base saturation, S = concentration of bases (meq kg^{-1}) and H = hydrolytic acidity (meq kg^{-1}).

Exchangeable Al was determined in the solution using the Sokolov method (Askinazi, D.L. 1975). Soil samples were mixed with 1M KCl (ratio 1:6.25), boiled to remove CO_2 and hot titrated using 0.01M NaOH. The amount of NaOH used for titrating corresponds to exchangeable acidity, which contains the total amount of H^+ and Al^{+3} in the soil absorbing complex. The second analytical phase involves fixation and precipitation of Al^{+3} as a complex silt of kriolit (Na_3AlF_6), with NaF added to parallel solution samples and repeated titration with 0.01M NaOH. The difference represents exchangeable Al (cmol(+) kg^{-1}).

Exchangeable P_2O_5 and K_2O (mg kg^{-1}) were extracted with ammonium acetate-lactate (A-L solution, pH 3.7; ratio 1:20). Exchangeable P_2O_5 was determined by spectrophotometry and K_2O determined by flame photometry (Egner, H. *et al*. 1960; Vazenin, I.G. 1975; Ginzburg, K.E. 1975).

Soil humus (%) was determined by the Tiurin method (Bielchikova, N.P. 1975; Orlov, S.I. and Grisina, L.A. 1981), which is a wet combustion technique similar to the Walkley-Black method (USDA, 1995). Humified soil organic matter was oxidized by solution of potassium dichromate with sulphuric acid; ratio 1:50(25); and excess dichromate determined by titration with ferrous sulphate (Mohr solution). However, the protocol determines 'humus' rather than soil organic matter or organic carbon, because only humified organic matter remains after thorough exclusion of un-decomposed plant and animal residues. Percentage humus was converted to % soil organic matter by multiplying by 1.724 (USDA, 1995).

The design of the field experiment on the sand-dune slope with a northerly aspect included the treatments: I. Perennial grasses (without geotextile mats, covered by shrub branches); II. Perennial grasses covered by Buriti mats; III. Perennial grasses covered by Borassus mats; and IV. Perennial grasses covered by coir carpet *(Photo 1).* Slope length was 5 m and the covered area 30 m^2.

The physical properties of the biogeotextiles show that the Borassus mats were somewhat thicker, had higher mass per unit area and smaller mesh sizes than Buriti mats (*Table 2*). The width of coir and straw-coir carpet was 2 m and thickness was only 1–3 mm.

The seeds from different wild plants, such us beach-grass (*Ammophila arenaria* L.), lyme-grass (*Elymus arenarius* L.), wood-reed (*Calamagrostis epigeios* L.), sedge (*Carex arenaria* L.), mugwort (*Artemisia campestris* L.), kidney vetch (*Anthyllis maritima* Schweigg) and baby's breath (*Gypsophila paniculata* L.) growing on the sand-dunes were collected in August and September 2006. Attempts to grow cultured seeds (orchard-grass (*Dactilis glomerata* L.), fescue red (*Festuca rubra* L.), Kentucky bluegrass (*Poa pratensis* L.), white clover (*Tripholium repens*

Photo 1. Field experiment on the sand-dune slope with a northerly aspect

Table 2. Selected physical properties of geotextile mats

Property	Borassus mats	Buriti mats
Material	Strips of Borassus palm *(Borassus aethiopum)* leaves	Fibres of Buriti palm (*Mauritia flexuosa)* leaves
Mean thickness (mm)	16	12
Size (m x m)	~0.60 x 0.60	~0.50 x 0.50
Mesh size (mm x mm)	30 x 30	40 x 40
Mass per unit area (g m^{-2})	950	520
Characteristics	Stiff, deformable	Flexible, deformable

L.) and alfalfa (*Medicago lupulina* L.)) in May 2006 proved unsuccessful. The cultured crops were unable to germinate due to the demanding edaphic conditions on the sand-dunes. The design of field experiment on the sand-dune slope with the southerly aspect contained the treatments:

I. Planting of cereal perennial grasses in May 2006, covered by shrub branches.

II. Planting of other perennials in May 2006, covered by shrub branches.

III. Planting of shrubs in November 2006, covered by shrub branches.

IV. Wild perennial grasses, sown in early spring 2007, covered by coir carpet.

V. Wild perennial grasses, sown in early spring 2007, covered by Borassus mats.

VI. Wild perennial grasses, sown in early spring 2007, covered by Buriti mats.

VII. Wild perennial grasses, sown in early spring 2007, covered by shrub branches.

VIII. Wild perennial grasses, sown in early spring 2007, covered by straw-coir carpet. Slope length was 7–10 m and the planted area was 48 m^2 (*Photo 2*).

The planted grasses were: beach-grass, kidney vetch and sedge, and planted shrubs or trees were: vilet willow (*Salix daphnoides* Vill.), currant (*Ribes alpinum* L.), rose (*Rosa dumalis* Bechst.), rowan (*Sorbus aucuparia* L.) and bird cherry (*Padus avium* Mill).

Two belts of palm-mats biogeotextiles were located on the front of the breached blowout, where the formation of an embryo sand-dune had commenced before spring 2006. The belts were designed as a checkerboard form from three rows of mats *(Figure 4).* One belt was located on the top of the highest newly formed sand-dune, while the other one was parallel with the first and 5 m inland. In total, 110 Borassus mats and 30 Buriti mats were used. The 72 sprouts of wood-reed, 80 sprouts of lyme-grass and 18 sprouts of beach-grass were planted on the squares of belts not covered by biogeotextile mats on

Photo 2. Field experiment on the sand-dune slope with the southerly aspect

31/06/06. Six graduated (every 10 cm) markers were inserted into sand-dunes at 5 m intervals in the middle of belts *(Figure 2).* These markers were used for periodic (every 10 days) measurement of topographic changes.

The white squares were covered by biogeotextile mats; the sprout ⊕ of wood-reed, lyme-grass or beach-grass were planted on the checkerboard squares as well as on the space between the belts. The markers (1–6) were inserted into the centre of dark squares.

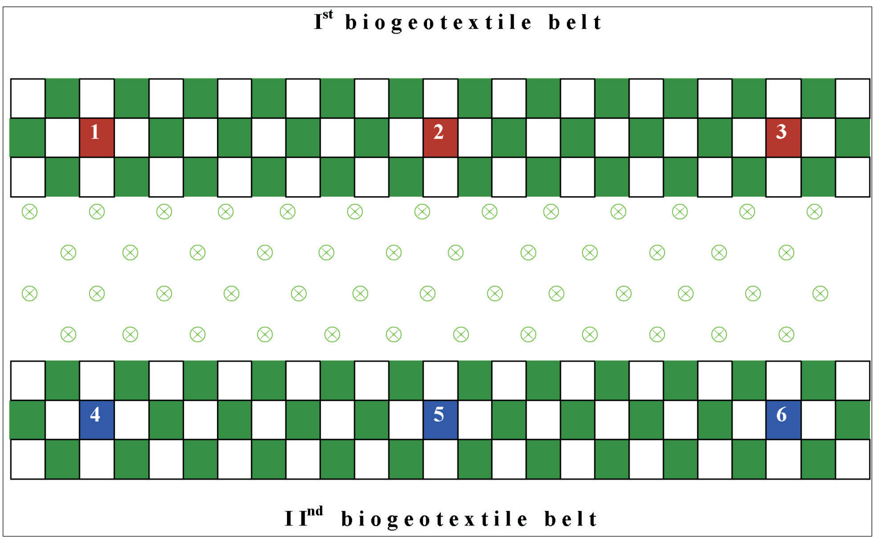

Fig. 2. The belts with biogeotextile mats located on the bottom of the breached 'corridor' and the slopes ('walls') of the breached sand-dune

Borassus mats, coir carpet and straw-coir carpet were used in the first set of field experiments in May 2006. A multi-species mixture of perennial grasses (Pg) consisted of 20% each of: orchard-grass, red fescue, Kentucky bluegrass, white clover and alfalfa. The mixture was sown into topsoil (0–5 cm). Soil sampling for soil moisture (% by volume) was determined using a Delta-T soil moisture meter type HH2. Measurements (6 individual measurements from each plot) were taken every 10 days on topsoil (0–6 cm) samples.

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

Results

The dynamics of soil moisture were investigated every 10 days during the vegetation growth period on the sand-dunes each year, but is represented by the mean data for 2007. The highest mean soil moisture content during the vegetation growth period in 2007 was under cover of Borassus and Buriti mats (*Table 3*). However, there was some time (23/05/07–22/06/07) when topsoil (0–6 cm) moisture under the branches fell to 0.6–1.4%. Moisture content was a little greater on the slope with the northerly aspect. Linear correlation coefficients of soil moisture values among treatments were: $r = 0.888–0.974$ ($P < 0.001$, $n = 19$) (*Table 3*).

Planting of grasses (treatments I and II) on the slope with the southerly aspect was performed on 31/05/06, and was followed by the planting of shrubs and trees (treatment III) on 23/10/06. The survival of planted species was high (*Table 4*), but growth rates were very low during the summers of 2007 and 2008. Very dry conditions in May and June impeded the development of young sprouts of sown plants, but most planted species survived this extremely dry period (*Figure 1*). Cover of the breached 'corridor' slopes on the sand-dune using biogeotextiles and established plants enabled the stabilization of the blowout and impeded further deflation.

A further objective was to nurture the accretion of the sand-dune basal 'floor' along the blowout. Planting sprouts of wood-reed, lime-grass and beach

Table 3. Soil moisture (% in 0–6 cm soil) on the sand-dune slope, southerly aspect, 2007

Treatments	Mean (n = 19*)	SE	Max.	Min.	SD
Pg (no cover)	2.46	0.38	7.40	0.60	1.62
Pg+Borassus	2.67	0.82	4.20	1.40	1.42
Pg+Buriti	2.52	0.38	7.60	0.30	1.60
Pg+straw-coir	2.16	0.41	7.80	0.10	1.75

*Soil moisture measurements taken every 10 days during the vegetation growth period.

Table 4. Survival of cultured plants and germination rates of sown perennial grasses

Treatments	Planted or sown species	Amount of the samplings (sprouts) on plot			
		planted	survived 2006	survived 2007	survived 2008
Planting grasses, May 2006 + shrubs' branches	Ammophila arenaria	60	43	58	37
Planting other perennials, May 2006 + shrubs' branches	Anthyllis maritima Carex arenaria	38 22	27 18	43 18	43 7
Planting shrubs and trees, October 2006 + shrub branches	Sorbus aucuparia Salix daphnoides Ribes alpinum Rosa dumalis Padus avium	15 12 15 2 1	– – – – –	14 12 15 1 1	12 12 15 1 1
Wildlife grasses, March 2007 + coir carpet	Artemisia campestris, Medicago lupulina and others	Sown	–	64	58
Wildlife grasses, March 2007 + Borassus	Artemisia campestris, Medicago lupulina and others	Sown	–	79	76
Wildlife grasses, March 2007 + Buriti	Artemisia campestris, Medicago lupulina and others	Sown	–	77	83
Wildlife grasses, March 2007 + shrubs' branches	Artemisia campestris, Medicago lupulina and others	Sown	–	69	77
Wildlife grasses, March 2007 + straw-coir carpet	Artemisia campestris, Medicago lupulina and others	Sown	–	66	78

grass was successful. The sprouts developed root systems and promoted herbaceous cover, both under geotextile belts and outside these belts. The cumulative curves (*Figure 3*) show evident changes in sand accumulation on belt I after winter 2006–2007 and much greater changes on belt II after winter 2007–2008. Most visible changes in sand-dune development were during warm periods (spring-summer-autumn) in 2006 and especially during 2008. Correlation among the mean data from three measurements every 10 days from biogeotextile belt I (x) and biogeotextile belt II (y) was r = 0.90 ± 0.058, P <0.001 (multiple regression R = 0.96 and regression coefficient R^2y/x = 91.31% (n = 56·3 = 168). More rapid accretion occurred on biogeotextile belt I (mean 26.7 cm) compared with 22.8 cm on biogeotextile belt II, with a mean accretion of 24.7 cm yr^{-1} (*Table 5*). The most evident accretion phases were during winter and, in some cases, in June and August. Significantly more accretion occurred in 2008, when herbaceous cover became dense. There was a significant (P <0.001) modified power regression (R^2 = 89.96%; t = 5.45) among sand-dune accretion under biogeotextile belts I and II.

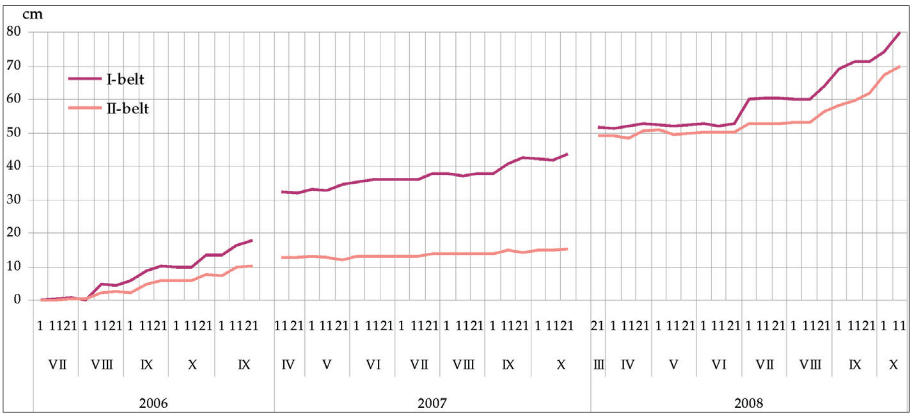

Fig. 3. Cumulative curves of sand-dune accretion on the areas of biogeotextile belts I and II. (Roman numerals represent months)

Table 5. Accretion (cm) of sand dunes on the breached blowout near Nemirseta

Year or index	Biogeotextile belt I, no. of markers				Biogeotextile belt II, no. of markers				Total mean
	1	2	3	Mean	4	5	6	Mean	
2006	38	26	17	27.0	14	11	11	12.0	19.5a
2007	15	26	20	20.3	18	20	21	19.7	20.0a
2008	23	35	40	32.7	62	26	22	36.7	34.7b
LSD_{05}	Among sand dune accretion in different years								7.80
Mean	–			26.7a	–			22.8a	24.7
LSD_{05}	Among sand dune accretion under biogeotextile belts I and II							7.85	–

Note: values with a different letter denote significant difference (P <0.05).

Discussion

Zaromskis, R. and Gulbinskas, S. (2010) identified three dynamically different shore segments of the Curonian Spit of Lithuania: relatively stable, transitional and accumulative. Our investigations were on the accumulative zone of the northern Curonian Spit on the slopes of a breached sand dune in Pajurio Regional Park on the Baltic coast near Nemirseta. Kask, A. *et al.* (2010) considered that "*waves and currents sort the abraded material so that coarser material accumulates closer to the outcrop of parent sediment and finer material is carried further. The sedimentation area is determined by hydrodynamic conditions and water depth. The depth and mean grain size correlation has confirmed that finer sediments accumulate in deeper and coarser ones in shallow areas. The glacial till in coastal areas and on shallow sills is subject to erosion by currents and waves which rework and redistribute the sand and silt components, while coarser particles (boulders and gravel) remain as lag sediments. Along the transport path to deeper areas, the sediment becomes progressively finer. Silt and clay particles settle in the deepest parts of the shelf. Sand forms deposits on the slopes of shallows where the equilibrium conditions for settling of sand particles exist*."

Similar characteristics of sand sorting were observed by Jarmalavicius, D. and Zilinskas, G. (2006). Particle size analysis reported in *Table 1* can be interpreted within this conceptual framework. The investigated sand dunes consisted of 96.1% sand, therefore soil moisture conditions were inimical for the growth of sown perennial grasses during dry summers (*Table 3*). Moisture conditions were better for the growth of planted local species on the bottom of breached sand-dunes. The planted species survived excellently and on the blowout slopes, but growth rates were very low during the summers of 2007 and 2008 (*Table 4*).

Biogeotextile cover enabled stabilization and restoration of vulnerable ecosystems on the Baltic coastal sand-dune. Firstly, geotextile cover prevented further deflation of the blowout. Biogeotextile cover increased moisture storage and encouraged vegetation growth (planted shrubs and grasses) (*Table 3*). Biogeotextiles also improved microclimatic and moisture conditions for the development of planted sprouts of wood-reed, lime-grass and beach grass communities.

In turn, this encouraged rapid sand accretion on the sand dune (*Figure 3, Table 5*). These processes contributed to the restoration of the breached sand-dune, sand accumulation and improved ecosystem functioning.

Time sequences of dune photographs are a useful means of studying dune dynamics (Fullen, M.A. and Moore, G.M. 1999). Further progressively rapid accretion of sand occurred on the 'basal floor' of the blowout some two years later after the completion of field measurements. *Photo 3* shows evidence of both sand accretion and the progressive thickening of plant cover.

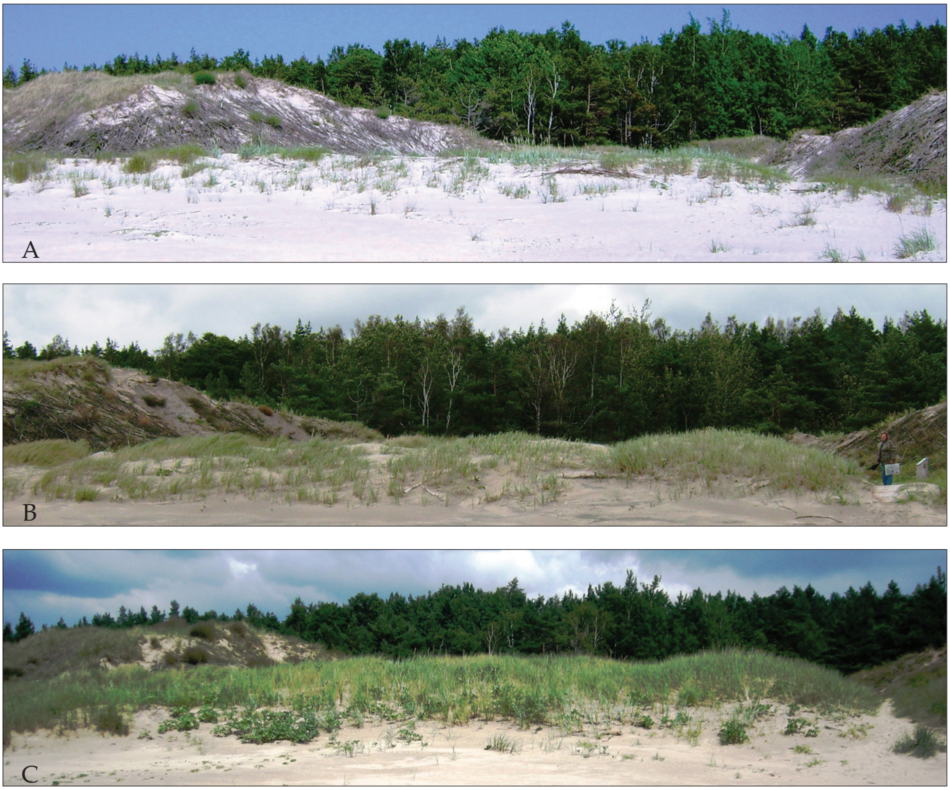

Photo 3. The breached blowout in the sand dune on the coast of Baltic Sea near Nemirseta.
– A = 2006; B = 2008; C = 2011

Conclusions

Two important conclusions must be drawn:

1. Covering breached sand-dune slopes with Borassus and Buriti geotextile mats, straw-coir and coir carpets and with branches of shrubs as well as planting local species of grasses, shrubs and trees enabled the stabilization of a blowout within a coastal sand-dune.

2. Covering the blowout floor using Borassus and Buriti mats and planting local species of perennial grasses enabled sand dune accretion by a mean of 24.7 cm per year over three years. This accelerated the restoration of a breached coastal sand dune.

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Hungary in Maps

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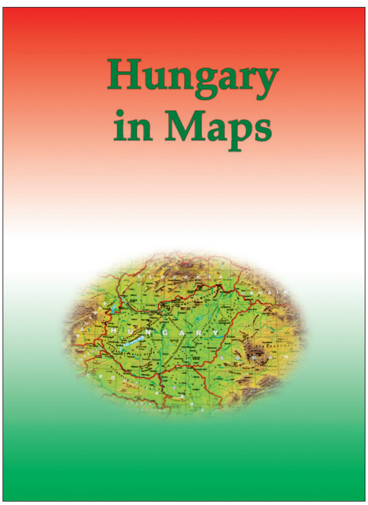
'Hungary in Maps' is the latest volume in a series of atlases published by the Geographical Research Institute of the Hungarian Academy of Sciences. A unique publication, it combines the best features of the books and atlases that have been published in Hungary during the last decades. This work provides a clear, masterly and comprehensive overview of present-day Hungary by a distinguished team of contributors, presenting the results of research in the fields of geography, demography, economics, history, geophysics, geology, hydrology, meteorology, pedology and other earth sciences. The 172 lavish, full-colour maps and diagrams, along with 52 tables are complemented by clear, authoritative explanatory notes, revealing a fresh perspective on the anatomy of modern day Hungary. Although the emphasis is largely placed on contemporary Hungary, important sections are devoted to the historical development of the natural and human environment as well.

In its concentration and focus, this atlas was intended to act as Hungary's 'business card', as the country's résumé, to serve as an information resource for the sophisticated general reader and to inform the international scientific community about the foremost challenges facing Hungary today, both in a European context and on a global scale. Examples of such intriguing topics are: stability and change in the ethnic and state territory, natural hazards, earthquakes, urgent flood control and water management tasks, land degradation, the state of nature conservation, international environmental conflicts, the general population decline, ageing, the increase in unemployment, the Roma population at home and the situation of Hungarian minorities abroad, new trends in urban development, controversial economic and social consequences as a result of the transition to a market economy, privatisation, the massive influx of foreign direct investment, perspectives on the exploitation of mineral resources, problems in the energy supply and electricity generation, increasing spatial concentration focused on Budapest in the field of services (e.g. in banking, retail, transport and telecommunications networks), and finally the shaping of an internationally competitive tourism industry, thus making Hungary more attractive to visit.



This project serves as a preliminary study for the new, 3rd edition of the National Atlas of Hungary, that is to be co-ordinated by the Geographical Research Institute of the Hungarian Academy of Sciences.

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