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Response of Eolian Ecosystems To Minor Climatic Changes

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ABSTRACT

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The coastal dunefield of northern Buenos Aires province has been affected by two main factors: rainfall changes and urbanization. It was determine a trend to humid conditions since 1960. The changes detected on the dunefield described were: (1) increase on the vegetation cover and deflation processes over active landforms; (2) decrease in dune migration rates; (3) increase on the beach erosion; (4) degradation of the dune landforms.

After one of the largest flood occurred in July 2001 in the eastern Buenos Aires, the intertidal lows of the active dunes began to be permanent flooded by an increase of the water table forming several shallow lakes. This fact induced changes on the dune ecosystem to adapt to new conditions. The lakes began to be colonized by algae and fungi probably transported by winds. Diatoms (*Rhopalodia, Nitschia, Navicula, Cymbella* and *Neidium spp*); chlorophytes (*Chlamydomonas, Cosmarium, Bulbochaete, Oedogonium* and *Chaetosferidium spp*); euglenophytes (*Euglena spp*). Cyanobacteria (*Nostoc spp*) and unidentified filamentous fungi grew between submerged macrophytes. In the bottom of the lakes appeared diatoms (*Cymbella, Rhopalodia, Surirella, Amphora* and *Nitzschia spp*.), dinofagellates and ostracods. On the lakes margins some species of vascular plants Spartina ciliata, Convolvulaceae (*Dichondra sp*, *Panicum racemosum* colonized the margins while the lakes got dry. An important bioturbation was also detected on the margins, caused by toads and worms that produced holes and tubes with complex trellis patterns, respectively.

ADDITIONAL INDEX WORDS: *Dune coast, climatic change, ecosystem.*

INTRODUCTION

The effects of past and future changes in climate, sea level changes and human activities on coastal dunes and associated beach systems have been of international interest in recent years (CARTER, 1991; PYE, 1990; NEAL, 1993; PYE and NEAL, 1994; ARENS and WIERSMA, 1994; SEELIGER *et al.*, 2000, HESP, 2002).

Eolian processes and landforms are sensitive to climatic changes and surface conditions that affect sediment supply and mobility. The response of eolian geomorphic system of the dunefield is directly related to minor climatic changes as well as to urbanization.

Because eolian processes and landforms are the result of interaction between winds and land surface, they are sensitive to changes in atmospheric parameters and surface conditions that affect sediment supply and mobility. Thus wind action is influenced by changes in wind strength and direction that may be the direct result of global or regional climatic changes as well as by changes in vegetation cover and sediment availability that are indirect effects of climatic change.

LANCASTER (1997) defined minor climatic change as a short-term change that may vary from decades to centuries. The changes involved are minor compared to those associated to glacial- interglacial cycles but are very significant in regional terms.

This paper analyses minor climatic changes occurred in the coastal dunefield of Buenos Aires province, during the last century and describes also the development of a new ecosystem in the dunefield after the large flooding occurred at Buenos Aires province in August 2001.

The purpose of the study is to describe the effect that an anomalous increase on humid conditions induced on the ecosystem of the coastal dunefield. Two climatic episodes at different temporal scales were detected. The first one involved an increase on the annual rainfall and a climatic tropicalization since 1960 and the other an anomalous increase on precipitation that caused one of the most intense flooding at Buenos Aires province.

METHODS

Regional changes in dune geomorphology and vegetation cover during the last 50 years were determined along 150 km of northern coast of Buenos Aires province based on vertical aerial black and white photographs ad landsat images taken in 1957, 1984 and 1995.

Biological samples were collected from the bottom, water, and margins of several interdune lakes in January 2002, March 2002 and January 2003. Date of monthly precipitation were provided by Municipio de La Costa.

Lake water samples were collected on March 2002. Chemical analysis of water were performed in Laboratorio de Análisis de Rocas, Departamento de Geología, Universidad de Buenos Aires University.

GEOLOGICAL SETTING

The coastal area reflects an important eolian morphogenesis in its evolution. The eolian landforms have suffer significant changes during the last 40 years as a result of climate variations (increases in the humid conditions) and antrhopogenesis (urbanization and forestation)

The dunefield covers an area of 275 km^2, with an extension of 150 km along the coast between San Clemente del Tuyú and Mar Chiquita, centered on 37° S. The inland margins of the coastal dunefield extend 2 to 4 km from the shoreline.

Dune formation began in the area approximately 540 years ago (ISLA, 1997) and has continued episodically untill the present day. The modern dune systems are important not only for nature preservation and recreation, but also in terms of shore conservation since they act as a natural source of sediments which prevent beach erosion during surgestorms.

Two main eolian types occur in the coastal dunefield according to the eolian dynamics: (1) active dunefield (Figure 1) (2) inactive dunefield. The first one has a high transport, depositional and erosion rates that avoid the vegetation cover and the soil development even so dunes may not migrate. The inactive dunefield is completely vegetated with *Adesma incana*

Figure 1. View of the active dunefield after the large flood occurred in July 2001. A. Transverse reversing ridges. B. Blow out dunes. C. Permanent lakes (a and b) formed after July 2001.

and *Poa lanuginosa*, or partially vegetated with *Panicum racemosum*, *Ammophila arenaria* and *Spartina Ciliata*.

The later dunes have no mobility but reactivation of the deflational processes is observed in different areas of the inactive dunefield.

The active dunefield consists of large transverse reversing ridges that comprise a linear E-W direction (Figure 1A). These dunes are surrounded and separated by undulating sand sheets with blowouts (Figure 1B) and complex parabolic dunes. Complex parabolic and saucer and thought blowouts are common landforms that can also be found on the inactive dunefield and interdune areas.

RESULTS AND DISCUSSION

Minor climatic changes

Total annual rainfall for Buenos Aires province between 1960 and 2000 shows an increase of 4.1 mm per year. The climatic analysis also reflects an alternation of more extreme dry and humid cycles and a climatic tropicalization (GONZALEZ and IBARRA, 2001).

The monthly precipitation for the area is about 71 mm per month reaching values up to 333 mm per month between July 2001 and April 2002 (Figure 2). The curve reflects the

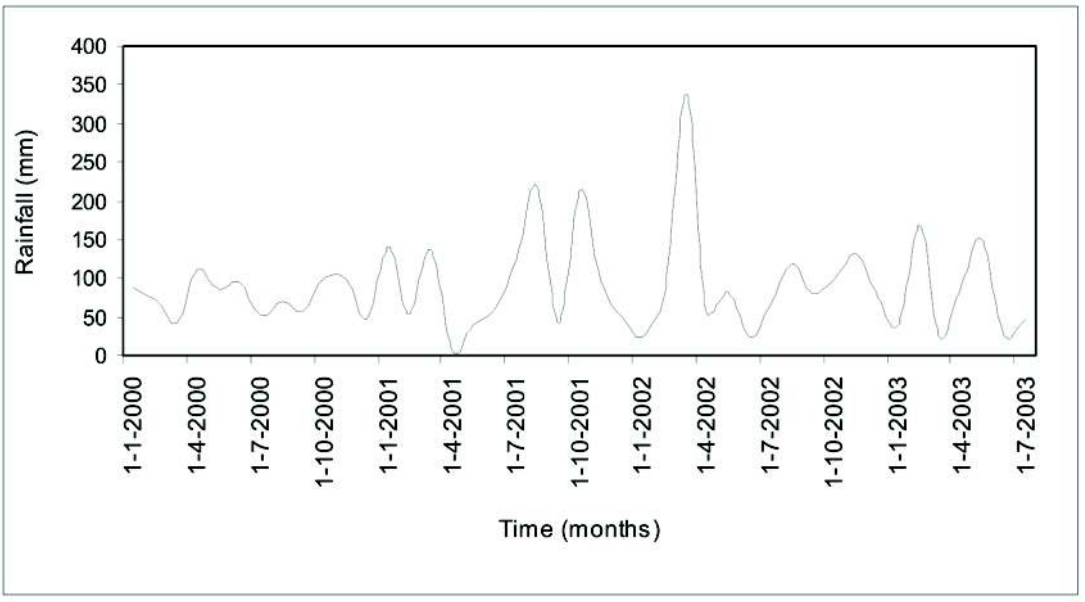

Figure 2. Accumulated monthly precipitation between January 2000 and July 2003. The curve shows an anomalous increase of the monthly rainfall between July 2001 and April 2002.

Figure3. Lake desiccation during summer dryer conditions. A. Worms tubes. B. Mucilages of diatoms and cyanobacteria. C. Vascular plants (*Spartina ciliata*) growth on the margin of the lake. *D. Bufo arenarum* holes.

beginning of a minor climatic change for the area, that have influenced not only the physical environment (morphological changes in the eolian geomorphical units) but also the composition of the communities living in such ecosystems

Nowadays the mean month accumulated rainfall reach the historical values even though the humid condition still prevails on the environment.

Dunefield evolution

In 1957, the dunefield was almost enterely composed of dry habitats represented by non vegetated sand plains or by sparsely vegetated hummocky dunes on the interdunal areas of the transverse dunes. During the following 20 years, humid habitats with dense herbaceous plant cover gradually increased. Afforestation of dunes began between 1935 and 1940 with *Pinus pinaster, Pinus insignis, Eucaliptus saligna, Populus deltoides, Acacia trinervis, Acacia saligna, Salix humboldtiana* and *Tamaris gallica*. In 2001 strands of mature trees covered about 50 % of the area. The forestation acts as a barrier for the sand transported by wind and generates changes on the eolian landforms. This effect resulted on the predominium of degradated dunes such as blow outs and complex parabolics.

Human contributing factors for aerodynamic changes result in direct and indirect effects. MARCOMINI (2002) described as *direct human effects*: (1) forestation, (2) urbanization, (3) changes on superfitial drainages, (5) surface impermeabilization (4) sand mining and as indirect human effect: (1) subsaturation of littoral currents (2) decrease on the eolian sediment supply because forest and coastal resorts act as barriers.

The increase on the humid conditions as well as the anthropogenesis, impacted directly on the dune aerodynamic during the last 60 years. The changes detected on the dunefield described were: (1) increase on the vegetation cover and deflation processes over active landforms; (2) decrease in dune migration rates; (3) increase on the beach erosion; (4) degradation of the dune landforms

Recent humid cycle

After the large flood occurred in July 2001 in the eastern Buenos Aires, the intertidal lows of the active dunes began to be permanent flooded by an increase of the water table of about 1,3 m in November 2001(Figure 1). This fact induced changes on the dune ecosystem to adapt to new conditions.

Several shallow lakes were formed in the interdune areas with different morphologies and dimensions. The largest ones are elongates of about 80 100 m length and 40 m width. The others are circular and occupied the deflation basin of blowout dunes (Figure 1B). The depth of the lakes varies between 0,3 to 1,4 m.

In one of the sampled lakes (Figure 1 C) the water measured parameters were pH 7.75, conductivity 196 μScm^{-1}, Na^{+} 0.32 meq/l, K^{+} 0.05 meq/l, Ca^{2+} 1.27 meq/l, Mg^{+} 0.11 meq/l, Cl^{-} 0.39 meq/l, SO_4^{2-} 0.02 meq/l, $HCO3^{-}$ 1.35, revealing its freshwater characteristics

After the flood, lakes began to be colonized by algae and

Figure 4. Mucilage masses produced by cyanobacteria and diatoms during drier stages. January, 2001

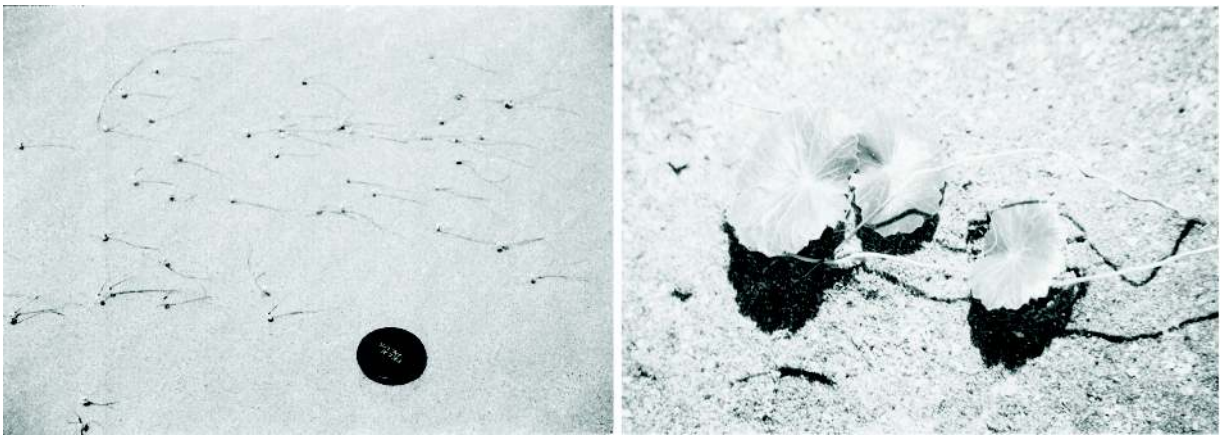

Figure 5. First vascular plants grown on the lakes margins of the interdune areas, favoured by the incresed of the wet conditions. A. January 2001. *Spartina ciliata* was the first species that appeared from seeds blown from inner lakes. B. March 2001. *Dichondra cericea* appeared on the lakes margins.

fungi probably transported by winds.

Diatoms (*Rhopalodia, Nitzschia, Navicula, Cymbella* and *Neidium spp*); chlorophytes (*Chlamydomonas, Cosmarium, Bulbochaete, Oedogonium* and *Chaetopheridium spp*); euglenophytes (*Euglena spp*). Cyanobacteria (*Nostoc spp*) and unidentified filamentous fungi grew between submerged macrophytes.

In the bottom of the lakes appeared diatoms (*Cymbella, Rhopalodia, Surirella, Amphora* and *Nitzschia spp*.), dinofagellates and ostracods.

An important bioturbation was also detected on the margins, caused by toads (*Bufo arenarum*) and worms that produced holes and tubes with complex trellis patterns, respectively (Figure 3). Toads also used those lake for breeding during summer. By the end of January a large number of toads of age around 1 to 3 month were found in the lakes. Numerous spiders (*Licosidae trochosa*) subsuperficially buried were found on the subaqueous margin of the lakes. During drier stages lakes were covered by mucilage masses (Figure 4), produced by cyanobacteria and diatoms and we found a large number of empty frustules of died diatoms. Actively reproducing diatoms, cyanobacteria (cocoid and filamentous forms), chorophytes and dinoflagelates dominated in the lake during rainy months.

On the lakes margins some species of vascular plants began to grow, favoured by the spring temperature and humid conditions. The first vascular plant grown in the margins was Spartina ciliata, from germination of seeds blown from inner lakes (Figure 5 A). Afterward *Dichondra cericea* (Figure 5 B) and *Panicum racemosum*) colonized the margins while the lakes got dry.

Despite the annual rainfall reach the historical values at present days, the lakes still have water. The water table of the free aquifer decreased very slowly because it received the water input from flooding areas inland. This minor climatic event caused an important change on the density and composition of the vegetation cover in the interdune areas, diminishing the activity and mobility of the active dunefield and the sediment supply.

In a near future subsaturation on the aerodynamic and littoral transport as a response to humid conditions and anthropogenesis could increase even more the erosion of the coastal area.

CONCLUSION

At decadal and annual time scales, eolian activity is strongly controlled by variations in precipitation in the coast of Buenos Aires province.

A climatic trend to humid conditions was detected along the coast of Buenos Aires since 1960. Degradation of existing transverse and barjanoid ridges is a product of this climatic variation and anthropic activity that increased the vegetation cover and soil moisture, and thus diminished the sediment supply.

The annual increase of precipitation produced a degradation of the active dunefield with a transition from transverse ridges to complex and compound parabolic and blow out dunes.

The increase in humid conditions as well as forestation enlarged the vegetation cover about 70 %.

The important flood occurred on July 2001 formed permanent lakes in the interdune areas, generating a new ecosystem with algae and fungi probably transported by winds into the lakes. Vascular plants began to grow on the margins, invertebrates (spiders and worms) and vertebrates (toads) used the margins of the lakes for their reproduction.

In a near future subsaturation on the aerodynamic and littoral transport as a response to humid conditions and human activities could increase even more the erosion of the coastal area.

The coastal settlements should have in consideration in their urban planning, the current climatic change and its impact on the ecosystem.

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