DYNAMICS AND EROSION/DEPOSITIONAL PROCESSES IN THE INTERIOR OF THE SAND DEPOSITS, SOUTHWESTERN RIO GRANDE DO SUL, BRAZIL

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ABSTRACT – The study area, called "Cuesta do Haedo" is situated in the state of Rio Grande do Sul, Brazil. It is characterized by the litotypes of the Guará, Botucatú and Serra Geral formations that cover the cuesta reverse side. In this area, there are outcrops of the Botucatú and Guará formations, called "Botucatú windows", which are the source areas for many of the sand deposits. The soils associated to these litotypes are susceptible to erosion, because they are poor in silt, clay and organic matter and show low fertility and aggregation levels which contribute to the sediments reworking. The aim of this study is to identify the erosive/depositional processes that occur in two farms where extensive livestock farming has been practiced. It is belived that this activity could potentiate the wethering agents that participate in the sand deposits dynamics. It is also an objective to produce a map of the sand deposits perimeter, in order to detect the expansion/retraction fronts. The identification of the accumulation forms and the transport ways of the sediments relating them to the upward slopes is also an objective of this project. The pluvial régime of the region, with 100 mm/month and 1,200 mm/year, and with concentrated periods of rains (160 mm/day), is considered a fundamental parameter in these dynamics. The end product of this study is a general portrait summarizing the main dynamics that cause the sand deposits formation and their expansion/reduction.
Keywords: Cuesta do Haedo, sand deposits, erosion, sandization, Southern Brazil.

RESUMO – *R. Verdum & V.G. Soares - Dinâmica e erosão/processos deposicionais no interior de depósitos de areia, Sudoeste do Rio Grande do Sul, Brasil*. A região de estudo denomina-se "Cuesta do Haedo" no estado do Rio Grande do Sul, Brasil. É caracterizada pelas litologias da Formação Guará, Botucatu e Serra Geral, que capeia o reverso da cuesta. Nestas áreas ocorre o afloramento da formação Botucatu e Guará, as chamadas "janelas de Botucatu", onde ocorrem muitos dos areais. Os solos associados a estas litologias são suscetíveis à erosão, pois a sua constituição tem reduzido conteúdo de silte e argila, assim como de matéria orgânica, apresentando baixos níveis de fertilidade e agregados, contribuindo para o retrabalhamento dos sedimentos. Este trabalho propõe-se a identificar processos erosivos/deposicionais e as microformas resultantes, definindo e cartografando o perímetro dos areais – um de rampa e um de colina – para a detecção das frentes de expansão/retração. Além disso, procura-se identificar as formas de acumulação e as vias de transporte dos sedimentos associando com as formas da vertente a montante. Considera-se fundamental nessa dinâmica o regime pluvial na região, isto é, com boa média de chuvas mensais (em torno de 100 mm) e anuais (1.200 mm), mas com episódios de chuvas concentradas (até 160 mm/dia). O produto final do trabalho busca estabelecer um quadro síntese, onde estão os registros das principais dinâmicas que desencadeiam a formação dos areais e a sua ampliação/redução, assim como as respectivas microformas que existem neles.
Palavras-chave: Cuesta do Haedo, areais, erosão, microformas, arenização, Sul do Brasil.

INTRODUCTION
CHARACTERIZATION OF THE STUDY AREA

In terms of location, it is the southwest portion of the state of Rio Grande do Sul which presents most expressive occurrence of sandy areas, devoid of vegetation. These areas took place particularly between latitudes 29º00' S and 31º00' S and longitudes 54º30' W and 58º45' W. Though the geographical coordinates are taken as delimitation parameters, it should be mentioned that the sandy area includes all the southwestern portion of the state from Rio Ibicuí, to the north, up to Rio Quaraí, to the south (that is, the international border with Uruguay). Eastwards, the outer boundary is the meridian of 54º30' W and westwards, the Rio Uruguay, in the international boundary with Argentina (Figure 1).

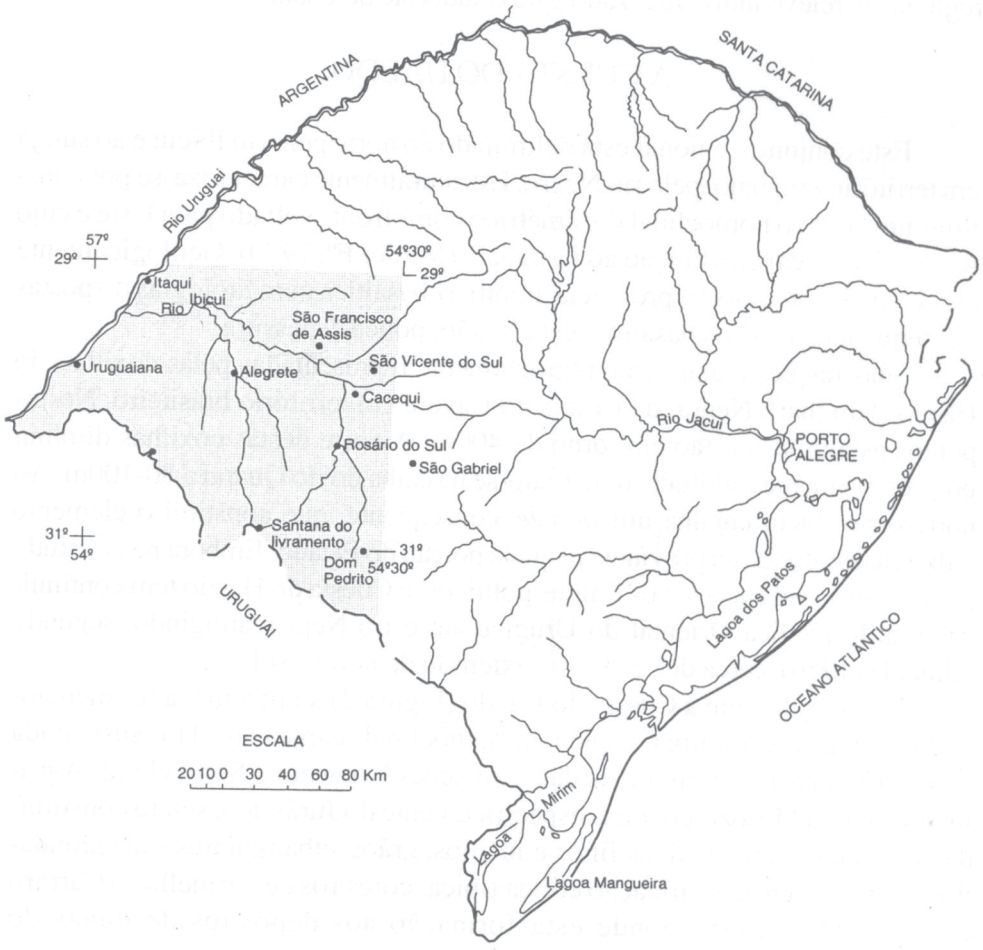


FIGURE 1. Localization of the occurrence área of "areais" (plural of "areal") in Rio Grande do Sul, Southwestern region.

In the State of Rio Grande do Sul, since the 70's, a fierce debate was installed on the existence of "deserts" and the "process of desertification", as landscapes and processes related to degradation of the fields in the southwestern region of the state. The Department of Geography of the Federal University of Rio Grande do Sul (IG/UFRGS) has developed investigations related to these topics of desertification, more specifically on the relationship or the lack of it with the process observed in the "gaucho Pampas" and known as "sandization" (*arenização;* Suertegaray, 1987).

In this sense, the genesis of the "areais" or areas with exposed sandy accumulations, the ablation dynamics and the associated landforms have been studied, making maps and calculations about the evolution of the "areais", as well as a time analysis of the use of the soils. Initially, it was important to separate the interpretation of the "areais" formation from the concepts of desert and desertification. In the first part of these studies, a bibliographic survey was conducted, which provided a theoretical base for the understanding of the context in which these areas were located, researching the historical knowledge of the use and ocupation of the soil in the áreas of "areais" occurrence. A second phase consisted in the delimitation of the study areas, observation and field data recording. In this pahse, it was possible to recognize the dynamic processes, hydric and eolian, which are acting on the "areais", by means of in situ visualization.

In each of the "areias, work was directed to the observation of the landform micro-relief. With this purpose, the area was visited, starting in the piedmont, where the first erosive processes took place. Field data were collected, photograph records and sketches were obtained, walking through the "areal" and reaching the contact area where the sands meet the grassy vegetation in the lowest portions of it.

As a result of this work, it was recognized that the application of this method allowed to establish some differences between the "areal de rampa" (sloping sandinized area) (Cerro da Esquina), anchored in the

rocky slope of the tabular relief, and that of the hills, located at the lesser inclined, middle slope (Cerro da Divisa), identifying the main local dynamic processes. It was possible to identify the erosion/deposition processes and the resulting micro-landforms, by means of photographic records, for their later interpretation.

MATERIALS AND METHODS

In the first moment, between 2006 and 2007, several experiments were done about the hydric/eolian dynamics of the sediments to detect their expansion or receeding in the "areais". In 2008, two field seasons were developed, in January and May, to verify, within the extent of the "areal", those areas with larger erosion potential. To this analysis, the influence of concentrated rains and the increase in the flooding plain of the streams was associated, being it forced by the rain itself or by the rising of the phreatic, superficial, underground level.

In the 2006/2007 field seasons, five measurements of the hydric/eolian dynamics were done in the hills of da Divisa, Alegrete and da Esquina, in São Francisco de Assis. Anemometers were located in the interior and the sides of the "areais" to establish a relationship between main wind and sediment transport directions, following the method developed by Sanchis and Verdum (2005). The anemometers were measured from their exposed side, which was measured in height in relation to the soil, to see the movement of the sediments in such sector, thus when smaller the height of the wind marker, larger would be the material accumulation. Five measurements were done in two areas in July 2006, October 2006, January 2007, April 2007 and August 2007:

a) The "areal" of Cerro da Divisa (Alegrete): in this site, two experiments were proposed, the A experiment, with three wind markers in a SE-NW position, and the B experiment, with three wind markers in a S-N position;
b) The "areal" do Cerro da Esquina (São Francisco de Assis): in this location, three experiments were done; experiment C (with three wind markers, in the southern end of the "areal"); experiment D (with three wind markers – in the interior of the "areal", in its southern portion) and experiment E (with seven wind markers, in the slope facing westwards).

In experiment C (São Francisco de Assis), in addition to the accumulation/deflation of the sediments, the horizontal advance or recession of the "areal" was verified (Figure 3**)**.

A second phase consisted in the delimitation of the study areas, observations and field records. In this phase, it became possible to recognize the hydric and eolian dynamics which act in the "areais" by means of in situ visualization. In each "areal" work dedicated to the observation of relief microforms was developed. With this purpose, the area was traversed starting in the piedmont, where the first erosion processes took place, notes were taken, and sketches and photographic record were collected, crossing the "areal" and arriving to the contact area with grassy vegetation in the margins of it and the lowest portions.

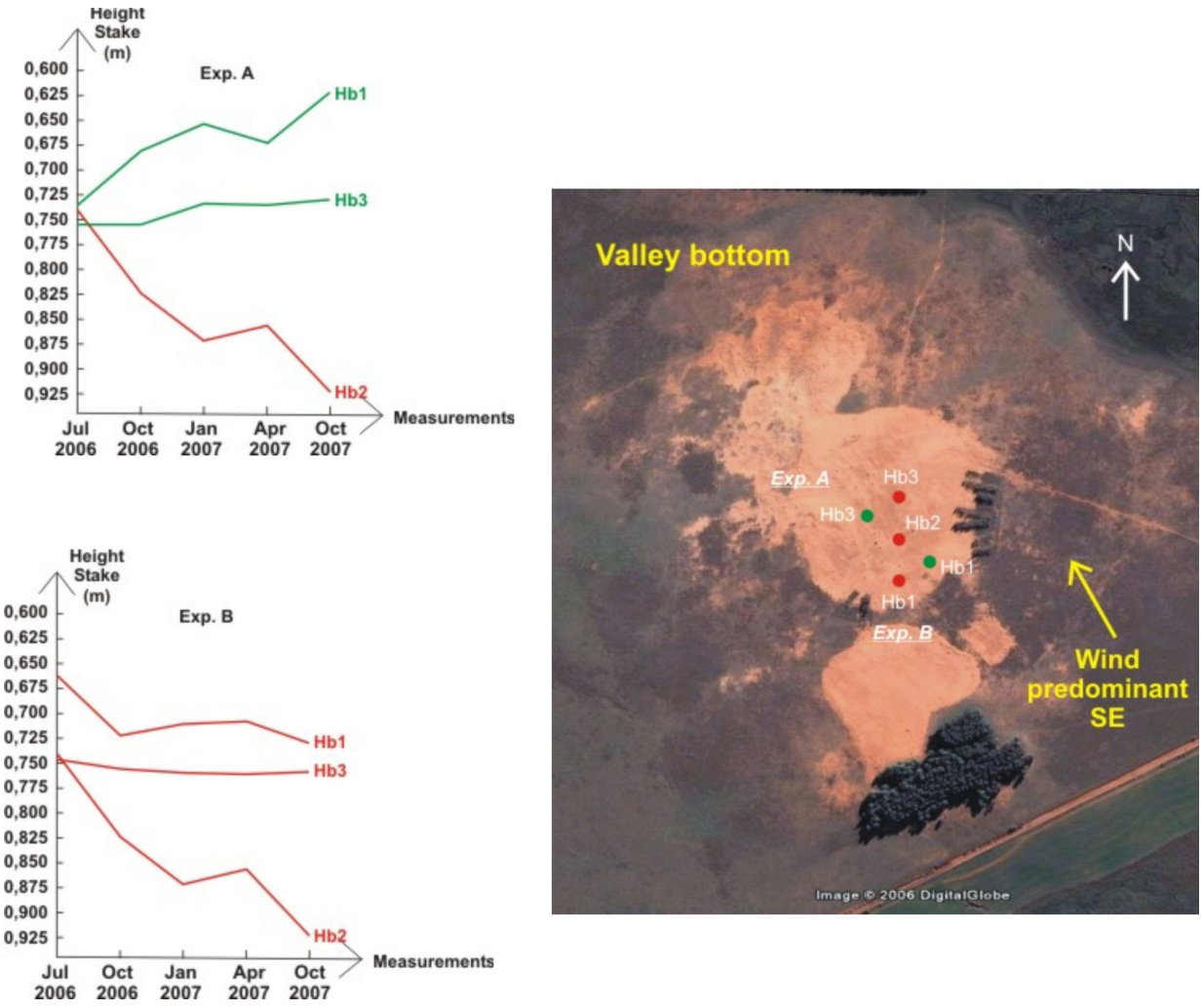
RESULTS AND DISCUSSION

"Areal" of Cerro da Divisa (Alegrete) – Experiments A and B

Once the measurements were completed, experiments A and B, in the Cerro da Divisa (Alegrete), indicated a movement of the sediments in a SE-NW direction, in which the main SE wind directions are oriented. The Hb2 site, a common point of the experiments A and B, is located at the top of a dune, which is more exposed to wind action. In the satellite image (Digital Globe – Google, 2006; Figure 2), it is also possible to see that in the northern portion of the "areal" the deposition of the sediments is more dispersed, what indicates that the "areal" is in expansion towards that direction, since in its S portion the material deposition is more expressive, with better defined margins to which the "areal" does not expand further.

In experiment A (SE-NW), the Hb1 wind marker recorded sediment accumulation because it was placed in a local depresion, propensous to material reception. The Hb3 wind marker, also recording sediment accumulation, is located in a favorable place for eolian action.

In experiment B (S-N), all wind markers presented loos of sediment and that, together with the result of the accumulation observed in the Hb3 wind marker of experiment A, provided evidence of sediment movement in a NW sense, where the other end of the "areal" is located.



*red color was used to represent the wind markers that presented sediment deflation and a green one for those that presented sediment accumulation.

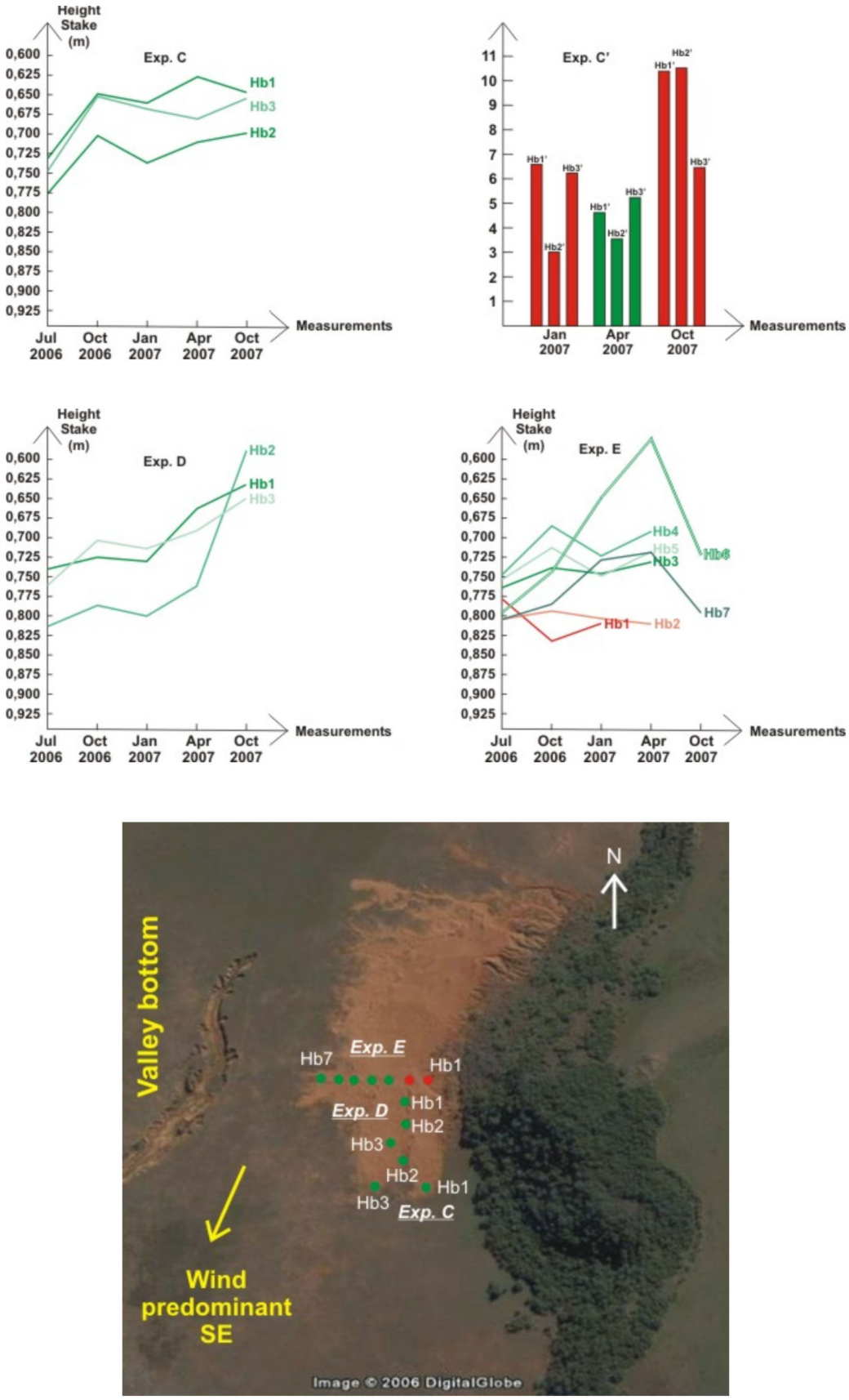
FIGURE 2. "Areal" of Cerro da Divisa (Alegrete): experiments A and B.

"Areal" of the Cerro da Esquina (São Francisco de Assis): Experiments C, D and E

In experiment C, the wind markers were located at the southern margin of the "areal", in the direction of dominant wind and in which it was supposed that the "areal" was expanding, by means of visualization in the high resolution images (Digital Globe – Google, 2006). All results pointed to a sediment accumulation, highlighting a similar sedimentataion behavior, graphically recorded (Figure 3). In the E-W direction, next to the hills, the Hb1 wind marker, even more to the east, represented a larger accumulation, whereas the Hb3 wind marker, indicated a smaller one.

In experiment C', both recession and expansion of the "areal" were recorded. Measurements were performed having as initial reference point the wind markers of experiment C. The first verification, observed in the field in January 2007, recorded an advance of the "areal", and the two following ones, in April and October 2007, recorded a recession and an advance, respectively (Figure 3).

In the field, a significant advance of the grassy vegetation was detected, because it has a larger capability of becoming established in the sediments and to stop the advance of the "areal". In that period of recession, April 2007, characterized because it was a period of higher moisture (Verdum, 1997), the dispersal of materials due to eolian action became very difficult, since the sediment particles were better aggregated. However, it may be seen as well that already in epochs of great rainfall events, in spite of the fact that the moisture parameter favoured the expansion of vegetation and acted as an agent of sediment aggregation, the displacement of material is quite large, and theferore the "areal" advanced (Figure 3).



*For a better visualization of the graphs, different shades of Green and yellow were used.

**In Graph Nº. 3, the red bars represent the advance of the "areal" and the Green ones its recession, that is, an advance of the vegetation.

FIGURE 3. "Areal" of Cerro da Esquina (São Francisco de Assis), experiments C, D and E.

In experiment D, the wind markers were located in a NE-SW sense, with the Hb1 marker located on top of a dune and being the Hb2 marker the one that recorded the largest accumulations. In all measurements, with the exception of the measurements of January 2007, there was sediment accumulation, what is providing evidence that there is an area to where the sediment is being translocated. Considering the scale in which the loss of sediment was recorded, this process was not significant, because the total sum of the perform, E measurements revealed a larger accumulation of materials comparing with the other five experiments (Figure 3).

Experiment E had seven wind markers organized in an E-W direction following the slope, in direction to the bottom of the valley, to measure the sediment transport, mainly through the surperficial runoff together with deflation. In the last two measurements, April and October 2007, some of the wind markers were displaced, one in April and the other Five in October. The Hb1 wind marker, on top of the slope, presented a larger loss of sediment, followed by Hb2, being thus the only two that recorded a loss in the total sum of the measurements. The rest of them presented accumulation, with the Hb6 marker havind a larger record and the Hb7 one, in the western margin of the "areal", the smaller one. It is appropriate to observe in the satellite image (Digital Globe – Google, 2006) that this is the western end of the "areal", being identified a pattern of sediment branching which, together with the results, is allowing to make a reading of the process of "areal" expansion, also in this direction (Figure 3).

CONCLUSIONS

The application of the field experiments lead to the following conclusions:

In the Cerro da Divisa area, the obtained data suggest a downstream transport of sediments (to North), due to the dominance of SE and SW winds; the Hb2 landmark, which is in the top of a dune, has the greater sediment loss by wind action.

In the Cerro da Esquina area, located at the edge of the sand deposit, measurements at periods of higher humidity show a retrocession of the sand deposit and its advance in dryer times. The experiments D (N-S) and E (E-W) show an east-west transport of sediments by water flows, and a north-south aeolic transport.

The results, in both areas, show an expansion of the sand deposits either by aeolian and pluvial regimes. Even so, it is observed that there are advances and setbacks in its expansion, as in a pulsar form, according to the weather variations, humid and dry periods.

All five experiments were quite clear about this expansion, if no contention work is done. Accordingly, it is relevant the divulgation of this and other works between the local communities and the authorities to further exploit the scientific work done at the university.

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