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Paleodunar Geosystems In The São Francisco River Course/Brazil

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Abstract: *The Brazilian semi-arid is home to important wind records with numerous formations of inactive dunes. The climatic and environmental changes occurring during the Quaternary are intrinsically linked to the genesis and evolution of sandy deposits in this region, taking into account their environmental characteristics and morphological arrangement. The aim of this study was to understand the paleodunar ecodynamics of this landscape, identifying the morphodynamic-climatic processes and the stability levels of this environmental system, aiming at the conservation of this ecoregion. The area investigated is very degraded and the processes of occupation and land use have caused significant impacts, presenting a risk of progressive destruction. The method adopted in this study was based on the morphodynamic approach proposed by Tricart, in the Geosystemic Theory and in the GTP Theory. The results point to a strong degradation linked to the inappropriate use of land and the indiscriminate withdrawal of vegetation, which becomes a morphological dynamics with a predominance of instability. Thus, the genesis of the natural and anthropogenic factors and processes determining the intensity of the degree of environmental impact was mapped, as well as, a conservation proposal was suggested for each category of landscape. In this sense, it is essential to monitor erosive processes, conserve native vegetation and implement a land use and land use management policy based on the precepts of social and environmental sustainability.*
Keywords*-Ecodynamics, Paleoclimatology, Paleodunas.*

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I. INTRODUCTION

Dunes are wind accumulations and their morphogenesis is inherent in the processes of erosion, transport and sedimentation leveraged by the wind. There are few premises for the genesis of dune bodies, such as: the winds and the availability of sediments. Thus, it is possible to affirm that the dunes are the most generic geoforms on the surface of the planet, being that about 85% of these are in the deserts.

However, in order for the sediment to be carried by the wind, it must have: (i) sufficient energy to erode and transport the sedimentary particles, (ii) regularity, blowing throughout the year for extended periods of time and not just in episodic blows and (iii) space to erode and transport the sediment.

In addition, only dry sediments are accessible to be eroded and transported provided the surface is devoid of vegetation or sparsely vegetated. Wind is an extremely selective transport agent, much more so than water, because it is less dense and less viscous, and it carries only very fine particles in suspension.

However, vegetation and surface roughness reduce wind speed, with sediment transport being hindered or reduced. Thus, Moura (2011)[1]talks about a vertical velocity and transport gradient, and states that as a consequence of the vertical wind speed gradient, the vertical distribution of sedimentary particle size can also be observed in a dune [or paleoduna].

In Brazil, active wind deposits can be classified into two types: the first denominated by Giannini et al. (2005)[2]of free dunes and sand sheets and the second, called semi-dunes or vegetated dunes, or paleodunas. The free dune fields consist of large individual masses of sand in motions, and the sand sheets are moving wind masses, without overlapping dunes and with negligible reliefs. The semi-dune dunes are those that are unique to coastal areas.

However, it is valid to emphasize that in Brazil there are about three geographic areas with interior dunes, highlighted by Giannini et al. (2005)[2]that has been the subject of several researches. These dunes are located in the following areas: Lower Rio Negro (AM), Pantanal (MS) and, in the middle São Francisco River (BA), the latter being the focus of this investigation.

The paleodunar fields studied here, border the lower-middle São Francisco river, being located in the municipalities of Barra, Xique, Arão, Remanso, Sento Sé, Casa Nova, Rodelas and Petrolina/PE, paleoeras, paleoclimas and paleoventos.

In addition, they are important hydrological reserves. Research carried out in the light of vertical electric survey, associated with the topographic characteristics of the sandy areas, indicates that the basement of the fluvial dunes studied can be located up to about 140 m below the current base level represented by the São Francisco River. The dunes constitute an important aquifer, representing a potential source of supply for domestic demands and irrigation in the future.

Diniz and Lima (2008)[3], based on an analysis of the profiles of the electrical surveys and topographic features, state that the basement of the dunes reaches 140 m below the current base level of the São Francisco River, with 50 to 150 m sand thickness wind. Thus, we would have an aquifer of good expression, representing an approximate volume of sandy sediments of 100 km (estimated length of occurrence of the dunes) x 70 km (average width) x 70 m (estimated average thickness), or 490,000,000,000 m^3.

However, understanding the morphogenetic and anthropogenic dynamics of these environments are of great importance, given that these are relics and are prone to the natural and anthropogenic degradation process. In addition, it is pertinent to emphasize that the modification of the vegetal cover interferes on the economic value of the water and directly on the process of soil formation, being these, some of the consequences capable of generating natural and socioeconomic losses through the intensification or progression of morphogenesis (Tricart, 1977)[4].

II. HISTORY OF THE STUDIES ON THE PALEODUNAS OF THE LOW-MIDDLE RIO SÃO FRANCISCO

The dunes and paleodunas existing on the banks of the São Francisco river are fluvial dunes formed from the process of deposition of sediments carried by the river in the course of its long history.

Research in these areas began in 1925 when Williams, H. E.[5], in his study "Geological and Economic Notes on the San Francisco River Valley" called the area of the "small Sahara" fossil dunes along the São Francisco. In the conception of this author the sands now stabilized by the vegetation would have been supplied by the São Francisco River, during the droughts, being then transported by the wind.

In the following year (1926), Moraes Rego[6] in his work "Geological reconnaissance of the western part of the State of Bahia", included alluvial and wind deposits, bordering the São Francisco River, in the Vazantes Formation. However, Domingues (1948)[7]gives a very strong consideration, attributing in his study "Contribution to the geology of southeastern Bahia", that at the stage of marked aridity during the last glacial period of the northern hemisphere, the São Francisco river would have assumed senile character in the Pleistocene, having presented marked sedimentation, with rambling course due to insufficient transport capacity to carry the entire sedimentary load.

Already in the 1956, King[8] in the study "The Geomorphology of Eastern Brazil" points out that the wind sands of the middle São Francisco River would result from the erosive cycle after the Old Surface, originating the Pliocene-Pleistocene planing. This author admitted that the main channel of the river followed for NW and ended in the river Tocantins, but current position that is conferred to him would have been conquered from fluvial capture.

In the year 1956 Aziz Ab'Saber[9], passing through the region of Barra and Xique in Bahia, sighted the existing dune fields there and called them "paleodeserto de Xique". It was from the observations made on the area at various times and by various researchers that we can now be sure that "it was an erg from a regional paleontology of the past, still uncertain, situated in central-eastern Brazil" (Ab'Saber, 2006, p.301)[10]. This author adds that the fixed paleodunas of this region originated in one of the semi-arid phases of the Upper Pleistocene, at a time when the general level of the seas were far below normal, that is, they experienced a period of marine regression.

Another study of great relevance on the subject is that of Tricart (1974) [11]in his research entitled "Existence de périodes seches au Quaternaire en Amazonie et dans les régiones voisines", where the author states that it would have occurred during the last glacial maximum of 18,000 years AP). At the time the river had an endorheic drainage, which ended in a lake and the current exorcist characteristic would have been acquired at the end of the last glaciation about 12,000 years ago AP. This Tricart [11]study was as relevant to the era as other researchers like Goudie (1983) [12]in the study "Environmental Change" and Schobbenhaus et al. (1984)[13] in "Geologia do Brasil", based on his theory to construct new indications and classifications of the area. Goudie (1983)[12]included the paleodunas in a world map of distribution of areas submitted to wind activities during the last glacial maximum. E Schobbenhaus et al. (1984)[13]admitted that these fields are the only example of dune formations of a quaternary desert environment in Brazil.

Another important study was highlighted in the Costa (1984)[14], in his work "Characterization and evaluation of dune environments in Fortaleza, Jaguaribe/Natal and São Francisco River", indicated that the

sands of these paleodunas fields would come from the São Francisco river and Serra do Estreito, which, as a topographical barrier , limited the field expansion to W (west). According to him, at the end of the last glacial stage, of the northern hemisphere, there would have been a humidification of the climate, allowing the modification of the endorheic drainage to exorcise. In this sense, the dunes would have been colonized by the vegetation, being stabilized, but endowed with a very fragile balance, and it was based on this characteristic, that this author suggested that the area of the paleodunas be inserted to the National System of Conservation Units, with conservation assured in permanent and mandatory.

However Barreto and Suguio (1993)[15]in a study called "Considerations on the age and paleogeography of the paleodunas of the middle Rio São Francisco, Bahia" and Barreto (1996) [16]in the study "Paleoenvironmental interpretation of the fixed dune system of the middle São Francisco river, Bahia ", They concluded from sedimentological data that the São Francisco River was in fact the only source of sand for the dune field. These authors compared the current sedimentary load carried by the São Francisco River with the estimated volume of wind sand between Barra and Pilão Arcado and concluded that it would take at least 100,000 years for all existing sand to accumulate in the area.

Recent studies by Pacheco (2014)[17] reaffirm the theory advanced by Barreto (1996) [16] that the São Francisco river in the stretch where several paleodunary fields are found (in the Bahian municipalities of Barra, Pilão Arcado, Xique [and addition], Remanso, Sento Sé, Casa Nova, Rodelas, among others bordering the "Velho Chico"), have for years built their wind deposits, which are generally barred by high geological formations in the area.

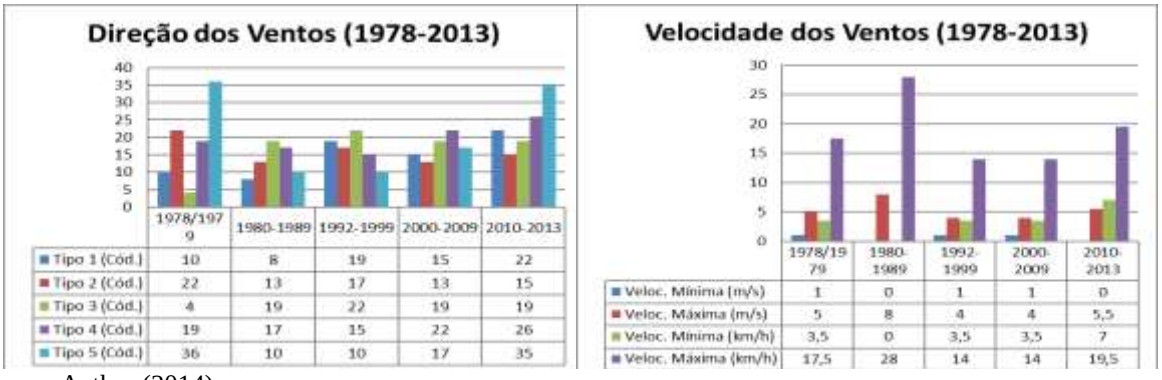
Said author, by surveying the prevailing winds in the areas of the municipalities mentioned above in the last four decades, concluded that these are not significant enough to sediment the sandy areas in the existing dimensions. Thus, it is proven that it is impossible for this wind to be responsible for the dune fields that measure up to 100 meters high, with an extension that can cover 7,000 km².

In this premise, the wind transport capacity can be evaluated according to its intensity, and the high intensity wind (from 48 km per hour) produces half a ton of sand, acting on the surface of a track with a meter wide, along a dune and for one day (Skinner; Porter, 1987)[18]. Based on this, it can be stated that the winds that occur in the areas described are not of high intensity and, therefore, are not sufficient for a significant transport of the quartz sands (Pacheco, 2017) [19].

Data related to the wind velocity and direction survey in the Barra and Xique area were granted by the National Institute of Meteorology (INMET) [20] through the Meteorological Database for Teaching and Research. The direction and speed of the winds were analyzed, being subdivided and presented in the following order: a) Decade of 1970 - data of the years of 1978 and 1979 were analyzed; b) Decade 1980 - climatological data from 1980 to 1989 were analyzed; (c) 1990s - data from 1992 to 1999 were analyzed, with 1990 and 1991 not being available in the INMET database; d) Decade of 2000 - information was analyzed from the years 2000 to 2009; e) Finally, the most recent data from the years 2010 to 2013 were analyzed, totaling 32 years.

Barreto research (1996) [16] indicates, in relation to the directions of the winds, in this region, that there is predominance of the easterly, south - southwest, north - northeast, southeast and south winds and speeds varying between the maximum 7m/with a minimum of 2.5 m/s. Thus, it is noticeable that the maximum speed was 24.5 km/h and the minimum did not reach 9 km/h, thus indicating moderate winds. The following charts show the direction and speed of the winds found in the studied areas.

Figure 1 - Synoptic graph (1978-2013) Figure 2 - Synoptic graph (1978-2013)



Source: Author (2014)

If we compare the data obtained by Pacheco (2014) [17] with data obtained by Pessoa (1979) [19]through the Barra e Remanso Meteorological Stations, we will see that the velocity of the winds at present is

similar to the winds of previous decades, since the actors identified mean velocities in the research area, around 1.8 to 3.1 m/s for the years 1928-1942 and 1972-1976.

In addition, studies of Barreto (1996) [16] show that, from 1925-1942, in the research area, there were north-northeast and east-lull winds, with velocities varying between 1.6 and 2.8 m/s. From 1979-1987 the intensities suffered small increase varying between 1.8 and 4.1 m/s.

Thus, it is possible to affirm that such velocities are important, but are not so significant as to affirm that the paleodunas under study were formed by the winds of those decades. However, despite being there as a morphological indicator of paleoclimates and paleoventos, these decades analyzed, are in some stretches stabilized by the vegetation and, in others, in constant movement by the wind action.

It is essential, therefore, to emphasize that there are several campgrounds, fields and micro campus of dunes on the edges of the São Francisco River that have not yet been cataloged and researched, and many of them are already inserted in private properties and subject to the suppression of vegetation and sands. In addition, others are already with their sands completely suppressed, their native vegetation decharacterized and with serious risks of extinction, due to the constructions and improvements erected by the settlement of these areas and arranged on these totally fragilized environments.

III. "NATURAL LABORATORY" OF PRETERATED RECORDS AND AT RISK OF EXTINCTION

The existing dune fields along the banks of the São Francisco River are true records of the quaternary of the Brazilian Northeast. They have in their genesis several remnants not yet fully revealed by researchers, as well as being available to be researched by different areas of knowledge (geological, geomorphological, climatic, biological, edaphoclimatic, ecological, geographic, hydrological, etc.).

However, this "natural laboratory" has serious risks of losing its original character or even extinction, since several damages have been suffered in the course of years of underutilization by the population living in its surroundings.

Within the researched areas it is still possible to find means considered morphodynamically stable, endowed with a series of conditions, such as: vegetal cover sufficiently closed to oppose an effective control to the triggering of the mechanical processes of the morphogenesis; moderate dissection, without abrupt incision of the watercourses, without vigorous river plats and slopes of slow evolution.

However, it is also easy to find areas with intense interference morphogenesis-pedogenesis in the environment considered intergrade, where instability is weak, pedogenesis gains advantage with a whole series of terms of transition to stable media. But if these advantages are not preserved, the transition may be to unstable means.

Unfortunately, in paleodunas there are already areas considered strongly unstable, where the work of morphogenesis is superior to that of pedogenesis, indicating the existence of [paleo] mobile dunes. It is worth mentioning that the highly unstable areas analyzed in this work can be analyzed from both the natural and anthropic points of view.

Most of the dune fields are part of Conservation Units (CUs), for example: paleodunas fields of Barra and Xique Xique/BA are part of the Dunes and Veredas Environmental Protection Area of the Middle São Francisco River; the fields of paleodunas of Casa Nova/BA are part of the Environmental Protection Area Lago de Sobradinho. The areas of PAs in Brazil are distributed as shown below.

Figure 3 - Map of UC in Units of Integral Protection and Sustainable Use Brazil

Source: MMA (2014); FUNAI (2014)

However, even being units to be conserved, they are not free to increase their intergrated and unstable areas, thus requiring positive interference in order to restore what is possible.

The previously mentioned Environmental Protection Areas (APAs) were created through decrees of the State of Bahia, aiming at the conservation of the sand mountains, as well as, aiming at a better management of the use and occupation of the sandy territories located at the borders of the São Francisco. However, the paleodunar fields of Rodelas/BA do not yet belong to any APA, even though there are several environmental agency reports discussing the vulnerabilities of these fields, as opposed to anthropic actions.

However, even though they are part of APAs, paleodunas are threatened by human action in their environment. Even in the decade of 1958, Ab'Saber [22] was already able to enumerate five types of degradation in the area of Xique paleodunas, namely:

live scrapes of debris from the dunes north of the set; anastomosed trails of goat transit through extensive stretches of the eastern part of the old regional dunes; derundation of the extreme periphery of the dune field in the eastern piemonte of the north-south crest of Serra do Estreito; exposed sands at the edge of the dunes in front of the greater bed of the São Francisco River; and the increase of the devastation in some other valleys once endowed with narrow ebb for rural agrarian activities (Ab 'Saber, 2006, pp. 303-304) [10].

However, with the process of industrialization and agricultural modernization these impacts have increased considerably. The following is a table with the main aggressions suffered by the paleodunar sites today, about 62 years after the visit of the geographer Aziz Ab'Saber to one of the sites already mentioned, the site of Xique Xique/BA.

Table 1 - Environmental damages at the paleoenvironmental sites of São Francisco

ENVIRONMENTAL DAMAGE	CONSEQUENCES
Illegal extraction of sand	Stoning of the original dune shape
Illegal extraction of native species	Sands vulnerability production
Dumping of solid waste	Contamination of sands and paleodunar soils
Evacuation of fresh effluents	Contamination of the sand and river
Opening of "tracks" under the dunes	No characterization of fields
Illegal sports practice	Erosion of sandy soils
Unsustainable tourism	Production of irreversible damage to paleodunar environments
Buildings without licensing on the dunes	Overlap production, erosion processes and total dune pollution
Retreat from the riparian forest of the river and the edges of the dune fields	Erosion of slopes and sediment transport to the riverbed
Planting of grasses for animal feed	Unprotected river banks
Irrigated agriculture on the banks of the river and at the foot of the dunes	Contamination of the river and groundwater (abundant in sandy subsoil)
Practice of grazing in the dunes	Trapping of animals and opening of paths
Predatory hunting and fishing	Reduction/extinction of fauna
Burned	Loss of soil fertility
Irregular occupation of APP areas	APP Area Degradation

Source: Authors (2018)

All areas of paleodunar fields bordering the São Francisco River can now be considered environments with a very high erodibility, impacted by incompatible anthropogenic actions. Therefore, it is important that environmental legislation does work, so that the damages caused to the paleodunar environments can be reversed or at least minimized, since they are environments of past ages, and can never be reconstituted.

In the fields of Xique, Barra and Pilão Arcado (figure 3) the impacts and their respective causes and consequences are visible.

Figure 3 - Environmental impacts in Xique Xique / Barra paleodunas

Source: Authors (2014)

All images in Figure 3 clearly demonstrate the various anthropogenic environmental damages that are practiced at the APA Dunas and Veredas of Middle San Francisco. We see in the images the following impact indicators:

(A) Removal of riparian forest for planting of grasses to feed the herd;

(B) Construction of residences on the dunes, causing devastation of the sands and vegetation native to the caatinga biome;

(C) "prainha" baths and sustainable (in) tracks in the fields of paleodunas, causing pollution of the dunes and the river, as well as, overlap / erosion of the sandy soils;

(D) Erosion at the foot of the dunes due to boat mooring, besides the creation of roads and paths on the dune, causing degradation and misuse of the soils;

(E) Clandestine water pipelines on the dunes, which may cause accidents with passers-by, in addition to the erosion of sandy soils;

(F) Devastation of the existing native forest on the paleodunas fields, facilitating the erosive vulnerability of the sands, due to the absence of vegetation to stabilize the dunes.

In relation to the Surubabel paleodunar field, called "Surubabel Desert" in Rodelas/BA, a Technical Visit Report of INEMA of 2012 published by the State Committee of the Caatinga Biosphere Reserve (CERBCAAT) of Bahia, reveals that it surprises visitors for beauty, degradation and accelerated desertification. The soil is almost without any organic material, and gives the impression that it is on the edge of an ocean on the banks of the San Francisco River.

It was possible to verify from the report numerous undesirably disposed residues, such as glass bottles, plastic bottles, disposable cups scattered in sand and water. In addition, the sanitary landfill of the city is on the way to the desert, being a typical sight, with lots of garbage and scavengers trying to take what can give sustenance to their families (CERBCAAT, 2012) [23].

Etchevarne (1992) [24] in his work "dune sites of the sub-average São Francisco, Bahia, Brazil" already affirmed that each archaeological site existing in the several municipalities of Bahia, were composed by the geomorphological unit – dunes. According to this researcher, it was possible to delimit the following Dunares Sets:

i. Port of the Mission, located in the municipality of Chorrochó, possessing about 2 km2 and with a height of approximately 30 m from the várzea;

ii. Outeiro, downstream of the São Francisco river, located in the district of Araticum, municipality of Rodelas, with a height of 20 m on the level of the várzea and a surface near 2,5 km2;

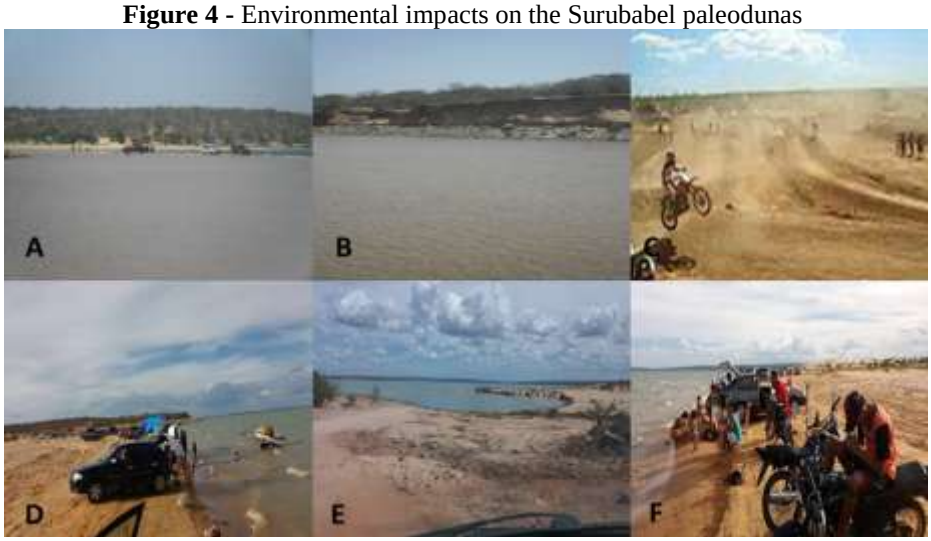
iii. Dunas de Jacó, also downstream, and in the municipality of Rodelas, has almost 3 km2, and extends for 600 m from the river bank;

iv. Dunes of Surubabel, in the municipality of Rodelas, comprising an area of 6 km2, and a height of up to 346 m (about 50 m above the level of the river);

v. Volta do Rio and Cabe do Boi (the last dunes), are located in the municipality of Rodelas, Volta do Rio has about 25 km2 and Cabe do Boi around 15 km2.

Thus, the Surubabel dune complex stands out among all the other groups, since it is the one that suffers the most interventions (Figure 4), due to its location and easy access, enables consecutive visits and intends more vulnerability and exploitation by of local society and visitors (Etchevarne, 1992) [24].

Figure 4 - Environmental impacts on the Surubabel paleodunas

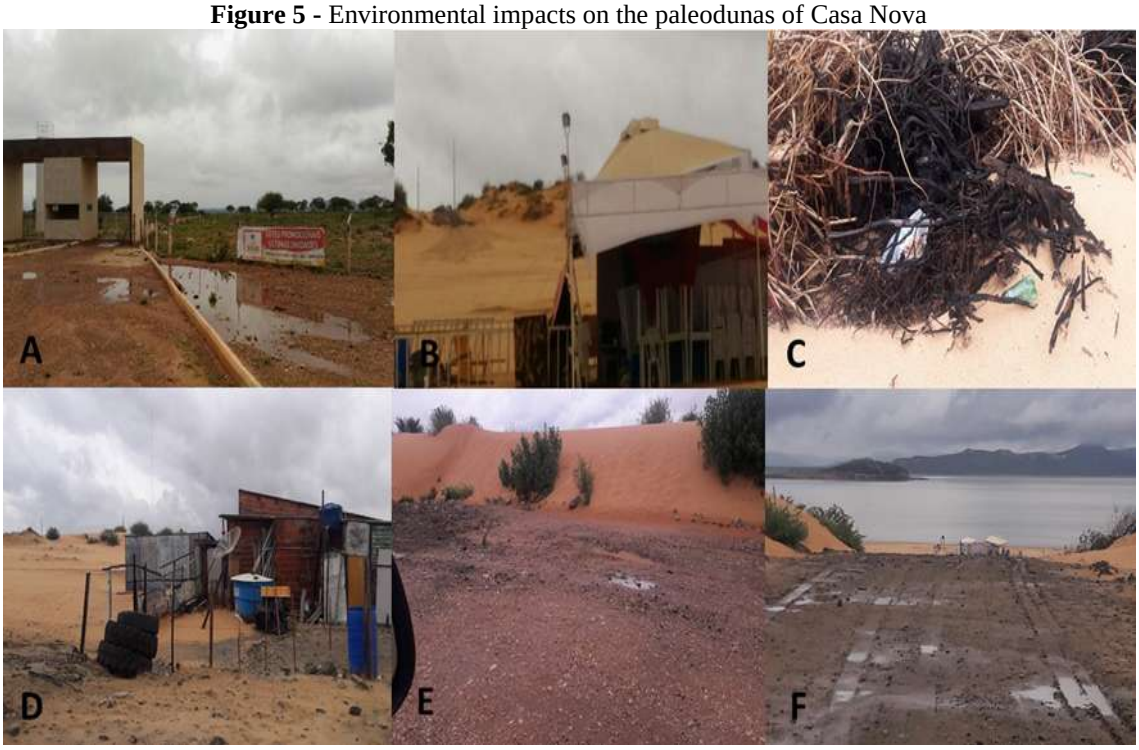


Source: Authors (2016)

With respect to the environmental impacts found in the Surubabel paleodunas, the following are:
(A) Car washing within the São Francisco river and everyday movement over the sandy areas;
(B) Marginal erosion due to lack of riparian forest removed with local settlement;
(C) Practice of sports not licensed by the environmental agencies, provoking processes of erosion and soil overlap;
(D) Pollution of the dune area by the visitation of the place and by the practice of baths and car washes on the banks of the river;
(E) Soil wear due to lack of vegetation and rainfall erosion;
(F) Dispersion of solid wastes and effluents in the area, in addition to the sediment transport to the river channel.

Still in this premise, it is possible to measure that the reality of the paleodunar fields in the municipality of Casa Nova/BA located in the APA Lago de Sobradinho, is not different. It has the same genesis as the other fields and its environmental impacts are similar to those of the other municipalities already mentioned. There is suppression of vegetation to give way to the parking of vehicles that at weekends and holidays will form the artificial landscape of the dune area along with a diversity of visitors. In addition, the dunes are being suppressed over the years, for private properties, with houses, animal enclosures and even condominium projects (Figure 5), it is already possible to see in the vicinity of the inactive dune fields.

Figure 5 - Environmental impacts on the paleodunas of Casa Nova



Source: Authors (2018)

The above images denounce the following environmental crimes practiced in these paleodunar areas:
(A) It is visible the advertisement of a construction project of a condominium in the dune area, which will consequently bring great environmental damage to this geosystem;
(B) A bar is set up in the Permanent Preservation Area (APP) of the São Francisco river, at the foot of the dunary fields;
(C) Denounces the inadequate discards of solid waste associated with burning on one of the fields;
(D) Demonstrates an invasive housing also located in APP, indicating direct and daily impacts in the study area;
(E) Demonstrates a serious environmental crime, where the dune area has been suppressed instead of building a flat and gravel "parking", for car parking of tourists and visitors;
(F) That translates the general situation of this ecosystem, where all the sand is withdrawn from the foothills of the dunar field to the edge of the river, thus facilitating the arrival of the vehicles for washing, producing even more erosive processes and suppression of riparian forest in the river San Francisco.

Research by Pacheco (2014) [17] has shown that the Casa Nova/BA paleodunas have not received adequate attention and adequate monitoring from local environmental agencies, and this has multiplied the environmental impacts practiced in this ecosystem. According to the Resolution of the National Council of the Environment (CONAMA) n. 1, dated January 23, 1986, in its Article 1, it is considered as environmental impact:

Any change in the physical, chemical and biological properties of the environment caused by any form of matter or energy resulting from human activities that directly or indirectly affect: I. the health, safety and well-being of the population; II. social and economic activities; III. the biota; IV. the aesthetic and sanitary conditions of the environment; V- the quality of environmental resources (CONAMA, 2012, p.924) [25].

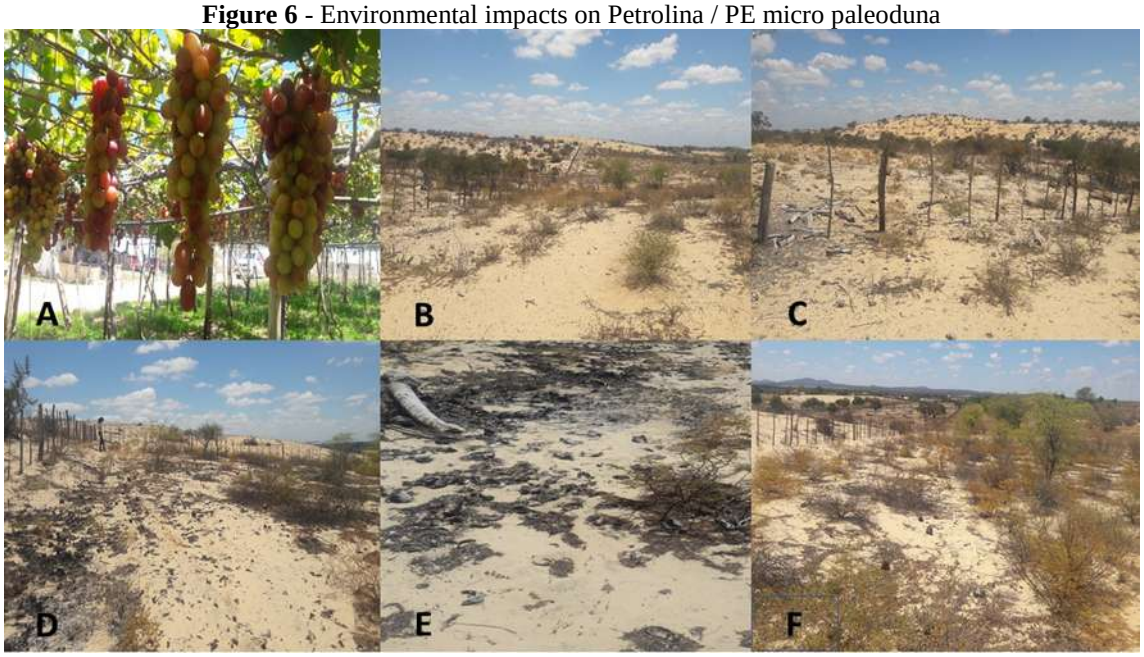
In this sense, every environmental impact constitutes the one that takes into account all the attributes described above and which are practiced by human beings who inhabit the many ecosystems but who do not have the knowledge and awareness necessary to care for the natural heritage still available.

At the edges of the São Francisco river in Petrolina/PE there are micro peliodunar fields, not yet cataloged and/or researched. In October 2017, through a training course held at the Municipal Environment Agency of Petrolina (AMMA), it was possible through a practical class to visit a private area with a request to suppress native vegetation and sands.

In this property is produced varieties of grapes for commercialization and export, aiming the profit and obtaining stabilization in the internal/external market. However, after careful analysis in the area, it was a micro paleoduna, which like the others, also has its genesis tied to the sedimentation work elaborated by the São Francisco river, in past times, that by retreat of its greater bed, today finds A little far from the riverbanks, however, is a great indicator of how much the river San Francisco suffered with the diminution of its volume and flow, and how much it retreated in its originality and characteristic past.

Despite the apparent concern of the landowner to give the "best" treatment to sandy soils, the local environmental agency was asked to suppress vegetation to advance agricultural production, as well as the suppression and sale of sand, with a view to so as to add up to the producing areas.

Figure 6 - Environmental impacts on Petrolina / PE micro paleoduna



Source: Authors (2017)

(A) There is suppression of sand to give way to the parreiral;
(B) There are enclosures on the paleodunar field to trace the division of use and occupation of the sandy soils in the property;
(C) Absence of the native forest typical of the biome and the dune area;
(D) Presence of residues of old productions (coconut palms);
(E) Presence of burning on the sands;
(F) "Islands" of native vegetation in the area of the micro paleoduna.
However, there was signaling by the owners to draw up a paleosystem conservation plan, as well as to keep 20% of the area intact (environmental reserve) as recommended by Brazilian legislation.

Therefore, the geosystems presented in this study are natural systems, however, social actors are an integral and essential part of nature, its evolutionary process and modification, so that if anthropogenic action occurs under nature, it can be recovered only depending on the way it will be viewed by society that acts directly on these natural constituents.

In this context, in order to deal with the impacts caused by society's actions in nature, it is necessary to use existing and legally available environmental management instruments to manage land use and occupation, in this case Paleoarean soils.

IV. ENVIRONMENTAL MANAGEMENT INSTRUMENTS AND PALEODUNAR CONSERVATION PLAN

4.1 ENVIRONMENTAL MANAGEMENT INSTRUMENTS

The Environmental Management Instrument (IGA) is understood as the systematization of technical and administrative procedures to ensure the continuous improvement and improvement of the environmental performance of an undertaking or an area to be protected and, as a result, to obtain the measures and practices adopted (Bitar; Ortega, 1998) [26]. In addition to the instruments there are also tools that optimize the studies and environmental analyzes.

Among the instruments and tools, there is the Environmental Impact Study (EIA) and Environmental Impact Report (RIMA); Environmental Control Plan (PCA) and Environmental Control Report (RCA); Recovery Plan for Degraded Areas (PRAD); Management Plan (PM); Environmental Audit (AA); Environmental Risk Analysis (ARA) and Environmental Expertise (PA).

All instruments and tools are available to positively contribute to the management and control of undue environmental practices, improving the internal performance of environmental agencies. In addition, some tools are capable of evaluating compliance with environmental policies, including compliance with current environmental legislation, in order to prevent lawsuits and reparations and indemnities.

In the meantime, it is necessary to draw up a plan for the management of protected areas, based on the management and territorial organization of soils, by means of zoning, rigorous inspection to avoid the elimination of the riparian forest of the São Francisco river, pollution, deforestation and other crucial aspects.

In addition, it is essential to have a concern with regard to the conservation of the sand, emphasizing the applicability of what is stated in CONAMA Resolution n. 10, December 1988, in its Art. 6, which states that the practice of numerous activities, including dredging and excavations that may cause damage or degradation of the environment and / or danger to the and biota.

Therefore, it is crucial to consider the applicability and/or enhancement of Environmental Education (EA) in the local school curriculum of the riverside communities living in the APAs, considering that this [Environmental Education] is an important tool to mediate the relationship between residents and the natural environment (paleodunas and São Francisco river), starting from the premise that the children who now inhabit the place in thesis, will be in the future, subjects who will conserve the natural patrimony of its place, if they are fomented to institute an environmental conscience , since with the adult population it is only possible to sensitize them to the need to conserve the environment from which they derive their own livelihood.

4.2PALEODUNAR CONSERVATION PLAN

The concern with the environment arises from the moment that the population grows and the economic activities progress. As environmental goods and services are being used by society, experiencing a growing deterioration, especially in places where human agglomeration and various economic activities develop, in the very near future we will have problems that can become irreversible, if compared to the time of nature's resilience.

The most important manifestations of the phenomenon of urban pollution cause a series of harmful effects that impose costs on society and the environment in which they are inserted. Conceptually, environmental damage, environmental degradation is defined in Article 3 of Law No. 6.938/1981[27] and is the adverse change in the characteristics of the environment, in a way that damages the health, safety and well-being of the population, create conditions detrimental to social activities, adversely affect the biota, damage the aesthetic or sanitary conditions of the environment or, finally, throw waste or energy in disagreement with established environmental standards.

It is possible to affirm that environmental damage is usually diffuse in nature, reaching a collective of people, and is difficult to verify and evaluate, since the activity can be produced today and the effects of the damage only appear after several years or generations.

Even with the growing idea about the importance of protecting the ecosystems and biodiversity of the planet, there are countless justifications that value conservation. Among these justifications is the elaboration of preventive management plans for environments with low resilience and essentially capable of storing information from previous ages, as is the case of the paleodunas discussed here.

Therefore, a Paleodunar Conservation Plan (PCP) is proposed, in which mechanisms for the prevention, control and conservation of natural environments will be available. In this understanding, the analysis of the landscape based on the processes concerning the operation of the systems makes possible the viability of a research focused on the stability and fragility dispositions of the environments investigated. Analysis of this magnitude leads to an orderly plan in preventive methods suitable for each type of landscape from instruments essential to greater planning and compatible with the ordering of the use by the society.

It is known that the studied areas are unduly occupied on the banks of the São Francisco River, at the foot of the dune fields. In addition to the construction of residences, there are also areas used for grazing, irrigated agriculture, radical sports and tourism, and these further sharpen the fragility of this geosystem.

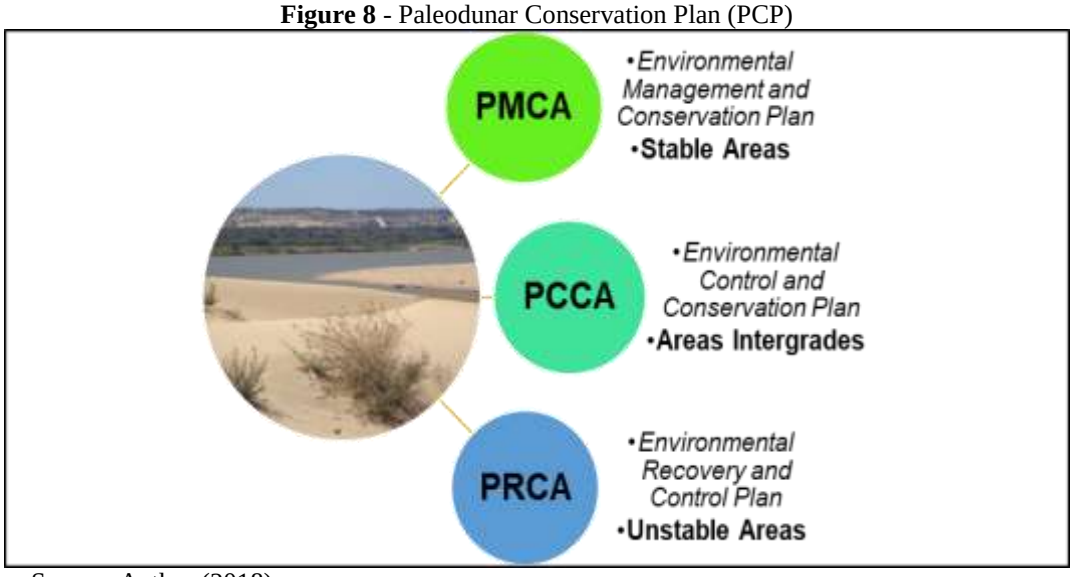
In this perspective, Tricart (1977)[4], through landscape ecodynamics, categorized the environments into three distinct types of morphodynamic means: stable media, media intergrades and unstable media. Stable medium is one that involves the notion of equilibrium and has vegetative cover responsible for the stabilization of the sands. The intermediate means are those that present intermediate morphodynamic behavior, referring to the gradual passage between stable and unstable media. In other words, it represents an area that is in the negative evolution phase, moving from a stable area to an unstable area. Thus, it is observed that the dynamics of this geosystem depends on the combination of several physical and socio-environmental factors.

Finally, the unstable media are marked by the action of morphogenesis on the pedogenesis and, according to Tricart, in these media morphogenesis is the predominant element of the natural dynamics and, determining factor of the natural system.

In addition to Tricart, Bertrand and Bertrand (2007)[28] deal with the GTP (Geosystem-Territory-Landscape) theory and treat the Geosystem as being natural (source), the Socioeconomic Territory (resource) and the Sociocultural Landscape (identity). In the meantime, both seek to overcome the false separation between nature and society.

It was based on the ecodynamics discussed by Tricart, and on the GTP Theory of Bertrand and Bertrand (2007)[28] that the PCP was elaborated, according to figure 8.

Figure 8 - Paleodunar Conservation Plan (PCP)



Source: Author (2018)

The presented PCP is usable for the three categorized environments, tend to suggest mitigating processes for the paleodunar areas under study. The Environmental Management and Conservation Plan (PMCA) is intended to be applied in areas that are still stable, with vegetation on the dunes, fixing them and avoiding degradation, so that they will not be damaged in the future because they are a fragile and vulnerable environment due to climatic and socio-economic conditions.

For areas that are already in the process of degradation, the application of the Control and Environmental Conservation Plan (PCCA) is indicated, aiming to maintain the control and the containment of the wastes in the areas that are in transition from the stable aspect to the environment intergrades It is crucial to create degradation restriction strategies in the areas in process and strategies to conserve what remains intact in some stretches.

Lastly, the Environmental Revitalization and Conservation Plan (PRCA) is highlighted, which emphasizes strategies for revitalization and reforestation (with native ecosystem vegetation) of the areas

considered to be highly unstable and, based on the results obtained, conservation, analyzing the resiliency capacity of the respective environments.

V. CONCLUSION

Through such a reality and the interdependence of such ecosystems, of imponderable value and environmental pertinence, in the face of its transcendent biological productivity and remarkable state of preservation, it requires a management that contemplates these multiple components of the dune landscape.

Thus, the proposals contained in the PCP should start with those responsible for the management of the APA's, who are responsible for managing the municipalities where the paleodunar fields are located, in partnership with local and regional environmental agencies, and essentially with the communities that are located around these environments, because it is the social actors who are living in this context, and can contribute in a positive way to this awareness.

It should also be noted that some of the environments studied are part of APAs and, according to the CONAMA Resolution, n. 10 of December 14, 1988, these APAs are conservation units designed to protect and conserve the environmental quality and natural systems existing therein, aiming to improve the quality of life of the local population and also to protect the ecosystems.

Therefore, according to CONAMA Resolution, APAs must have an ecological-economic zoning aiming to establish norms of use according to biotic, geological, urban, agropastoral, extractive, cultural and other conditions, aiming for greater balance and conservation of the area.

It is congruent to point out that the paleodunary systems described in this study are one of the subsystems that are part of the fluvial plains that are victims of the intense and conflicting use with the indispensability of deep intervention of the environmental organs for the effective legislative protection and applicability of the preservation and conservation measures.

With regard to the issue of environmental planning, research practices have been increased with the purpose of identifying modifications. In this understanding, the analysis of the landscape based on the processes concerning the operation of the systems makes possible the viability of a research focused on the stability and fragility dispositions of the environments investigated. Analysis of this magnitude leads to an orderly planning in preventive methods suitable for each type of landscape, from instruments essential to greater planning and compatible with the ordering of the use by society (Pacheco, 2017) [19].

Therefore, this research does not have a conclusive character and it is not intended to exhaust all the debate on the subject in focus, considering the relevance of this discussion in the management and management of the environmental territories, especially those that represent a testimony that the geosystems and ecosystems are changeable both by their natural dynamics and by the social dynamics that surround them. Thus, research and debate continue to understand the issues listed here as infinitely searchable, changeable, and worthy of a critical, reflective, and reconstructive rethinking.

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