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Dynamics and management of the coastal dunes of the Landes, Gascony, France

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ABSTRACT: The rectilinear sandy coastline of the Landes, Gascony, is receding fast with serious repercussions for the dune system. The coastal dune was established in the nineteenth century to protect the forest, and was artificially-shaped into a rampart 12 to 15 m high running 230 km from north to south, on which the 'oyat' (*Ammophila arenaria*) was planted. The dune fell into disrepair, but work began again in 1945 with the aid of heavy machinery. Good results have been obtained by the Office National des Forêts (ONF) on dunes having the domanial status; however, total mastery of the aeolian dynamics has been difficult to achieve in a chain of dunes whose height is now excessive (over 20 m), and which is attacked by the sea, forming high sandy ridges. Damage has become extreme in those private or communal areas where maintenance is insufficient and the influx of tourists high. The sand is now invading the forest and threatening dwellings. Fundamental research on aeolian dynamics and vegetation cover by the Université de Bordeaux III on behalf of the ONF and the Conservatoire du Littoral has produced 'cartes écodynamiques' on a scale of 1 : 5000. These maps detail the forms of destabilization and distinguish the 'faciès progressifs' from the 'faciès régressifs' of the vegetation cover. They are used for deciding on the technical action comprised by the 'plans d'intervention'. Preventive methods have evolved from physically disruptive procedures, which destroyed the ecosystem, to more careful forms of action. Undulating relief with a lower aerodynamic resistance are now allowed and provision of a greater diversity of stabilizing vegetation is now under study.

INTRODUCTION

The Aquitaine coast is an almost rectilinear shoreline 230 km long, the only interruption being in its middle, the inlet to Baie d'Arcachon. The relief of the coastal zone between the Landes lagoons and the sea evolved from the Flandrian transgression which was able to move onshore enormous quantities of sedimentary material produced or deposited on the shelf there during the cold periods of the mid-Quaternary era. Incorporated several times into shoreline complexes, they provided the prevailing west winds with considerable quantities of quartzitic sand which accumulated as dunes during three successive phases. This paper considers the management strategies for this area of large-scale dynamic dunefields.

COMPLEXITY OF THE DUNE SYSTEMS OF AQUITAINE

The 'Sable des Landes' Formation, which stretches more than 100 km inland, contains both

fluvial and aeolian sand and was established at the end of the last glacial period. The Formation has undergone a long and active pedogenesis and has developed a highly-evolved podzolic soil with a strong humo-ferruginous 'alios' (hardpan). During the Holocene period (last 10000 years) two dune systems developed. First, the 'dunes anciennes' of parabolic shape involving strong onshore winds and an extensive grass cover are associated with Neolithic episodes. These dunes have soils with highly-developed humic horizons on which grows an ancient mixed forest comprising maritime pine and Atlantic hardwoods. Second, the 'dunes modernes' are barchan-shaped forming long ridges parallel to the coastline, up to 7 km wide and often exceeding 50 m in height. The delivery of sand from the sea was so high during the late-Holocene that the vegetation was unable to stabilise it, leading to the final enclosure of the lagoons. These dunes with their poor

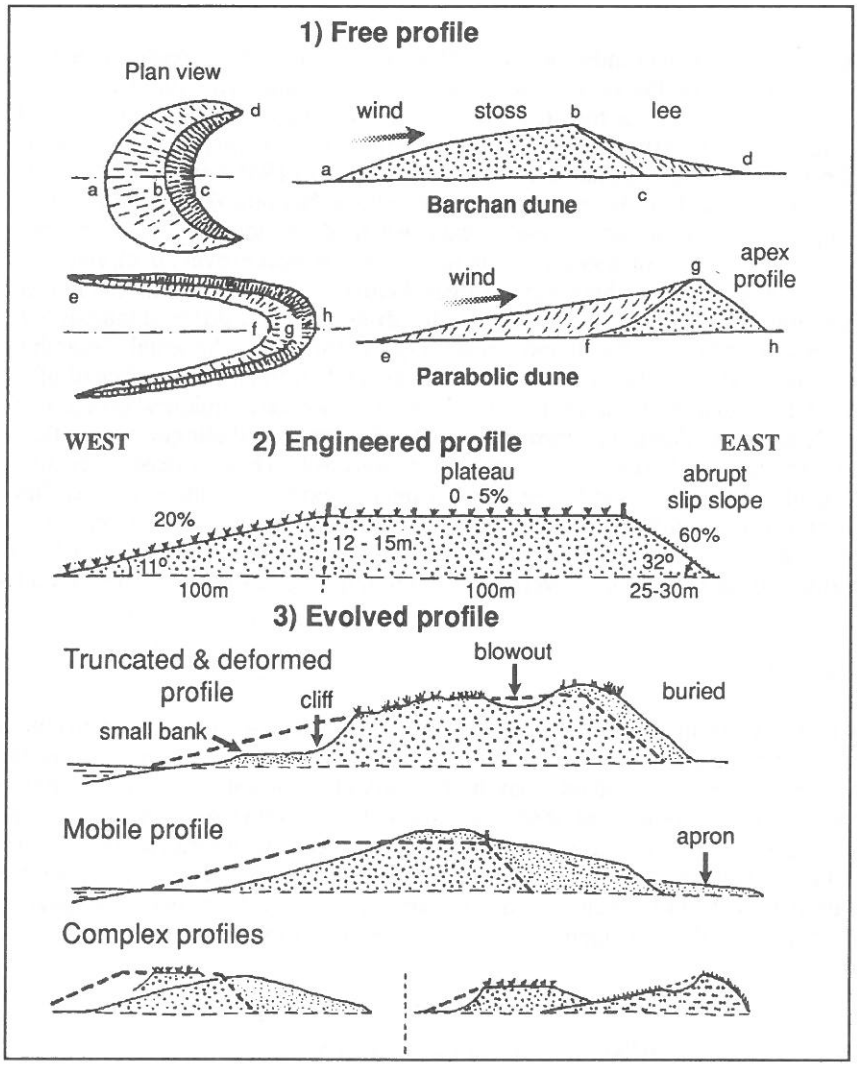

Figure 1. Types of profile across the dunes of Les Landes.

vegetation were mobile again during the Middle Ages, and moved from time to time until the eighteenth century. On Brémontier's initiative, they were extensively consolidated by planting maritime pine in the first half of the nineteenth century. Once the forest was established on the dunes, they became threatened by continuing dune transgression, manifest as long tongues ('pourrières'), as small dunes transverse to the coastline ('dos de baleine' configuration) or as low parabolic dunes ('en rateau').

THE MODIFIED DUNE PROFILE

To protect the forest, which in the nineteenth century was the main economic resource of the region, the dune was designed as a rampart to temper the force of onshore winds, the impact of blowing sand on the forest margin, and the corrosive effect of salt spray. Under the direction of an engineer named Goury, the whole length of the coastal dune was profiled after 1827. The sand from the beach was held in place by palisades which were raised as they filled, and by planting gourbet or oyat (*Ammophila arenaria*).

The profile which was sought, and which later came to be known as the 'profil idéal', sloped gently to the coastline at an angle of 10 to 11 degrees, had a sub-horizontal plateau, both of which were planted, reinforced on the landward side by a bank of active sand resting at 30 degrees. The width of this construction was about 150 to 200 m and 12 to15 m high. Most of the coastline was remodelled in this way, first in the Landes (104 km) and later in the Gironde (120 km). Well-maintained until the beginning of the twentieth century, the system with its quasi-stable equilibrium had shore-parallel vegetation zones running from east to west. Near the coast and especially on the backshore, the primary vegetation consists in mainly halophytes: *Agropyrum junceum*, *Cakilé maritima*, *Salsola kali*. On the active dune, the sward of *Ammophila arenaria* includes the blue thistle (*Eryngium maritimum*), the bindweed (*Calystegia soldanella*), the maritime forb (*Euphorbia paralias*), the sand cheese-rennet (*Galium arenarium*) and in places the 'épervière' (*Hieracium eriophorum*) and the cottonweed (*Otanthus maritima*).

On the landward side of the dunes and in the 'lette'- a longitudinal depression situated behind the dune - a ground-covering herbaceous vegetation predominates. The most frequent vegetation here is the 'immortelle' (*Helicrysum stoechas*) with a wide floristic variety including graminates such as the 'canche' (*Corynephorus canescens*) and the fescue (*Festuca juncifolia*), papilionacates (*Ononis repens*, *Lotus corniculatus*), caryophyllacates such as the pink (*Dianthus gallicus*) and the silene (*Silene portensis*). *Jasione maritima* also often occurs. The sea grape (*Ephedra distachya*) and the artemesia (*Artemesia maritima*) are sometimes found instead of the 'immortelle'. Total cover and stability of the sand is ensured by a lower layer often including two types of both moss and lichen. The edge of the forest is marked by the bush and shrubs species of the Atlantic coastline, such as heather (*Erica scoparia*) and gorse, or shrubs of the undergrowth, particularly the arbutus (*Arbutus unedo*), behind which the forest varieties, maritime pine, holm-oak and cork-oak adopt a characteristic wind-shield configuration. The dunes, which suffered considerable damage in the great storms of 1912, 1917 and 1926, also suffered from the almost total lack of maintenance during the world wars. During the Second World War the dunes, which were a restricted military area, were used as a source of aggregate to construct the Nazi blockhouses. In 1945, the dunes were in a serious state of disrepair, being eroded by the sea, dissected by blowouts, or hollowed-out as gullies. First, the Service des Eaux et Forêts, and then from 1966 the Office National des Forêts (ONF), began to undertake extensive renovation. From 1950, but especially between 1960 and 1980, with mechanical aids, the 'profil idéal', or as near as possible to the ideal, were imposed all along the dune front, and

Figure 2. Low tide at Soulac, showing the German blockhouses on the foreshore. Erosion here has been 200m since 1945.

were entirely replanted with marram. This was a considerable effort, and two points require clarification : - 1. Rebuilding of the dune has led to permanent retreat of the coastline, and the dune scarp is now very close to the edge of the forest, that the exposed sand, entrained by the wind, often damages. 2. The progressively increasing height of the dune, often exceeding 20 m, exacerbates the aeolian dynamics, either on the seaward side by direct deflation, or at the rear of the dune where strong vortices occur.

SHORELINE RETREAT

The present evolution of the dunes involves the subtle combination of four main factors : marine erosion, aeolian action, the dynamics of vegetation cover, the number of tourists which increases every year.

Since 1945, the retreat of the undefended shore has nowhere been less than 1 m/year on average and often exceeds 2 m. For example, on particular stretches of coast to the south of Soulac, erosion has reached 4 m/year, and similar figures have been noted close to the headland at Cap Ferret and on the flanks of the inlet into the Baie d'Arcachon around Pilat and Gaillouneys. Marine attack does not occur uniformly along the coastline. In areas of extreme erosion, the low gradient slope of the seaward dune has either been completely or partly replaced by a sandy cliff, the height of which may reach 12 to15 m. Of the 232 km of sandy coastline, 196 km have recently been attacked directly by the sea, and have either active or fossil cliffs (Table 1).
Between these erosion zones there are areas of temporary aeolian sand accumulation on the back beach normally covered by a growth of *Agropyron*. The entire foredune ridge migrates slowly southwards owing to the oblique north-west winds and the coastal drift is estimated at between 600,000 and 1 million m^3 a year.

Table 1. Cliff types along the coast of the Landes

	Type	Height	km	%
Active	Low	1 to 3 m	31.5	16
(57%)	Medium	4 to 7 m	37.4	19
	High	>8 m	43.9	22
Fossil	Low or medium	1 to 7 m	52.3	27
(43%)	High	>8 m	31.2	16

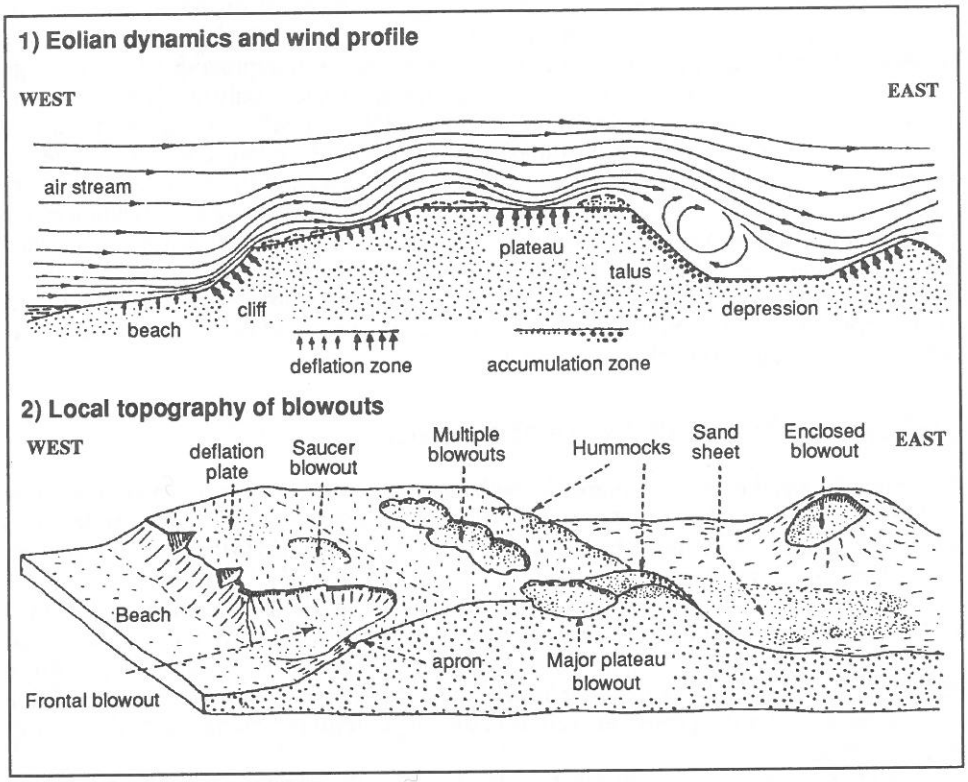

Figure 3. Cross-section and schematic diagram showing the morphological units across the dune complex. The lower diagram shows the types of blowouts.

INTENSE AEOLIAN DYNAMICS

Initially aeolian erosion affects the cliff and the higher the cliff, the greater the effect, leading to breaches and corridors which in time may enlarge into gully, and then into wide frontal blowouts. On the frontal ridge and the plateau, wind turbulence creates deflation hollows, developing into 'blowouts', behind which sand chute and plume deposits are fixed by marram. The vegetation cover of the marram becomes disturbed by the hummocks of various sizes, leading to large discrepancies in shoot density indicative of the health of the

dune. Even if the depression behind the dune had originally accentuated topography, the down stream turbulence of the wind flow may create a second line of blowouts.

Accumulation forms differ according to their position across the dunes. On the foredune ridges above the beach, *Agropyron* may trigger growth. Moving sand in transit predominates on the seaward slope and the plateau, but the psammophilic vegetation survives annual accumulations of around 0.3 to 0.6 m, which in time raises the height. Accumulations of bare sand appear behind the main dune ridge; these are tongues of sand known as 'pourrières', forming as single features along the axes of the blowouts, or as a coalesced form along the length of the stabilised dune. Average quantities of sand reaching the rear of the dune may, over a long time, exceed 25 m^3 /m/year. Landward migration of these ridges may be spectacular, reaching 12 m/year at Cap Ferret, where the dune is now invading the forest and threatening dwellings. The Grand Dune de Pilat southwest of Arcachon is an extreme case where an active dune 110 m high at its highest point overlooks a zone of erosion reworking both 'dunes anciennes' and 'dunes modernes'. A precipitation ridge 70 m high is invading and directly engulfing the forest. Sand reaches the lette only in extremely stormy weather.If sedimentation is excessive, it leads to faciès régressifs, causing artemesia and marram to take precedence over the immortelle. The edges of the forest, which take the full brunt of an intense sand deposition, high winds and salt spray, suffer from high mortality and consequently retreat. The natural evolution is therefore towards a modification of the profile and the evolution of a relatively more undulating relief than the artificially-created one. Dune managers could be tempted to forever reprofile the dunes with heavy machinery, but apart from the very high cost of such work, a question mark remains concerning its usefulness. Each time reprofiling is undertaken, a great amount of the biological value, which takes so long to develop, is eliminated.

ECOLOGICAL MANAGEMENT OF THE DUNES

For non-urbanized dune environments, both managers and researcher workers are now convinced of the soundness of a certain number of principles, sometimes known today as the 'soft engineering' methods, based on ecodynamics, as opposed to the harder techniques of civil engineering. These include:

1. Sand to be kept as much as possible at the front of the dune edifice. Two simple techniques have proved particularly effective: one, plastic nets in front of the abandoned cliffs and frontal gullies, making it possible to reconstruct a foredune; two, surface stabilisers in deflation areas allowing *in situ* fixing of large volumes of sand and favouring spontaneous vegetation growth,as well as in the longer term providing a useful supply of organic matter.

2. Reduce the perturbation of the wind by the cliffs, through the accumulation of sand thus lowering the windward slope. Irregular topography should be eliminated, particularly cornices. Obviously, any modified slope must be covered and planted as soon as possible. It is not a problem if some sand is lost to the sea as it will assist in energy absorbtion. Since the retreat of the Landes coastline is now inevitable, it should be accommodated rather than opposed, by reducing to a minimum the degradation on the dune environment.

3. In retaining the existing vegetation on the dune it is essential to minimize extensive mechanical reshaping of the dunes, especially those which result in bare sand. At sensitive points of the soft techniques - netting, systematic cover of deflated areas and planting with fertilization - should be employed. The experimental use of waste slurry has given excellent results, although non-damaging spreading techniques remain to be developed.

This principle accepts a shift from fixed, fragile profiles with relatively high relief to smoother, more undulating topography. Such environments may be considered quasi-stable in which the relief and vegetation offer minimum resistant to the wind.

Figure 4. A replanted dune showing the engineered profile.

4. Differentiation of vegetation cover is of crucial importance; trials are underway in the south of the Landes to systematically use *Agropyron* in association with marram on the seaward dunes.

5. Dunes should not be permitted to grow excessively in height. The engineers of the nineteenth century through a mixture of intuitiony and experience established an optimal crest height of 12 to 15 m, while today many ridges are 20 to 25 m high.. Such an obstacle absorbs too much wind energy to be controled easily.

6. It is important to protect dunes from tourists.

CONSENSUS MANAGEMENT BETWEEN TECHNICIANS AND RESEARCHERS

The principles of 'ecodynamic management' of the dune have been applied successfully to management on ONF on lands purchased by the Conservatoire du Littoral at Hossegor and Cap Ferret, and systematically, but in a less intensive manner, throughout the dune area. Fundamental research (beach dynamics, aeolian dynamics, vegetation ecology) has been undertaken by the Laboratory of Applied Physical Geography at the University of Bordeaux III. Extensive in-service training has ensured the progressive transfer of the techniques of environmental analysis from researchers to managers. In 10 years, nearly 7000 man-hours of instruction have been offered. Highly effective relationships have developed from this collaboration ensuring follow-up and, hopefully, the permanent collaboration. The managers now have three documents at their disposal: first, an atlas of the types of dune on the Aquitaine coastline comprising 22 maps at a 1:25000 scale. The first edition, was published in 1981, the second edition in 1990. These maps relate satellite imagery with field measurements and serve mainly for planning in addition to helping one to appreciate the rapid evolution of the dune systems. Second, ecodynamic maps at scales of 1:5000, showing the characteristics of the environment in kilometre segments. Plans, which may be

superimposed on the maps, outline proposed joint actions by the managers and scientists. Third, there are technical notes on the dunes of the Aquitaine coastline, composed of information on definitions (geomorphology, geodynamics, botany, techniques), providing both researchers and dune workers, from the labourer to the engineer, with a common vocabulary for facilitating communication and ensuring the transfer of knowledge.

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