ACCRETION - EROSION IN THE BEACHES OF THE CANARY ISLANDS (SPAIN).

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ABSTRACT

In the beaches under study on the island of Grand Canary, we are identifying and measuring the intertidal annual cyclic processes of accretion and erosion, starting from the topographical movements of the strand.

These processes:

a) We are analyzing and interpreting these in the framework of the physical and geographical interdependences, and as responses to the more internal evolutions of the morphodynamics, in the sedimentary environments in question,

b) and permitting the definition and calculation of some indices of sedimentary gains and losses, of interest to coastal planning and management.

INTRODUCTION AND OBJECTIVES

In the opinion of Charlier (1987), the mathematical calculation and managment of the sedimentary volumes, through observation of the topographical movements is, actually, the optimum method for the identification, measurement, and interpretation of the accretion and erosion processes (gains and losses) in sandy beaches.

If the topographical movements refer to the intertidal zones, as it happens in this work, we are obtaining answers to the more internal evolutions of the beach environment morphodynamics, in a greement with the outline of Wright and Short (1983).

The sedimentary dynamics of the beaches develop, to a very important proportion, between the shoreline and the breaker line. With a range of the astronomical tide of up to 2.82 m. (as is the case in the Canaries), the intertidal zones have sufficient amplitude to support truly valid investigations, referring to the accretion - erosion processes, in the beaches under study.

The accretion - erosion processes represent effects resulting from some determined causes. Knowing and understanding the "effect - cause" duality, we can predict "causes - effects" through the numerical model.

The modelling of these processes develops various conceptual stages. We will order these from botton to top, depending on the best level of abstraction and generalization:

a) In the first phase, the works in the field aimed at identifying a physical model, in which predominates the selection of basic qualitative characteristics.

b) The translation of qualitative data to quantitative data constitutes a complex process, which passes through intermediate partial modelling steps. The representation of the selected descriptive parameters, of adequate scale, culminates in the establishment of a quantitative stage.

c) And in the quantitative phase, we apply, essentially, the mathematical method. This establishes an abstract problem which serves, preferentially, for the analysis of general questions.

The actual work, in the framework described, is situated between the qualitative phase and an intermediate semi-quantitative phase.

On the other hand, the estimations and indices of the sedimentary gains and losses in the beaches are useful, in the present form, in coastal planning and management. Nevertheless, the making of decisions needs to be based on an analysis of the whole of the physical processes and handicaps which appear in these situations.

GEOGRAPHICAL SETTING

The sandy beaches under study (figure 1) are located on the island of Grand Canary (Spain). The descriptions of the same are presented in condensed form in table 1.

ACTUAL TECHNIQUES

The study is based on the following techniques:

1. Elevation of the topographical profiles of the monthly studies, mostly in 1986. We are using the method of geometric levelling (by altitudes), as developed and described by Martínes et al (1987 a, 1987 b, and 1987 c).

2. Calculation of the relative volume of the sands, by the trapezoidal method, in agreement with Puig Adam (1979). The volumes correspond to an intertidal strip, previously determined, and from a convenient base level. The contrast of the series of relative volumes, in relation to the lowest value, measures the sand gains or losses.

3. Oceanographical analysis of the annual gains and losses of the beach sand. For this we have recourse to:

- the surface meteorological predictions
- and visual observations of the surf from ships "en route", in the Canary environment. The data is taken from the "Oceanographic Atlas of the North Atlantic Ocean", in its sucessive revisions.

With observations of the surf we analyze, for the greatest part of the Grandcanary coast:

- the maximum possibility of presentation/altitude, indefinite depth, of the significant "swell" and "sea" waves in a certain direction (pattern of the directional surf),

Beach	Location	Morphology	Approximate dimensions		Genetic classification after Suárez Bores (1980)
			Length in m.	Maximun width in m.	
Sardina del N.	Costa N. (Gáldar)	in cove	85	45	$GG^{o}_{o,o}$
Las Canteras	Costa N. (Las Palmas)	subcoves in a large cove	3100	90	$GDdGGDdG^{1}_{o,o}$
El Hombre	Costa Oriental. (Telde)	in cove	224	91	$GG^{o}_{o,o}$
El Burrero	Costa Oriental. (Agüimes)	in cove	205	30	$GG^{o}_{o,o}$
El Inglés	Costa Meridional (S.Bartolomé)	rectilinear	2700	100	$Gg^{o}_{o,o}$ (2)
La Bajeta	Costa Meridional (S.Bartolomé)	convex towards the ocean	470	100	$g^{1}_{o,2}$
Maspalomas	Costa Meridional (S.Bartolomé)	rectilinear	2103	50	$gD^{2}_{o,2}$

Table 1

Descriptions of the beaches of Grand Canary (Spain) under study.

- as well as the annual percentages.

Once the annual processes of accretion and erosion have been measured and interpreted, we can define two operative indices:

- estimation of the sedimentary support capacity,
- and the sedimentary variability.

INDEX OF SEDIMENTARY SUPPORT CAPACITY (S.S.C.I.)

This index defines the difference between the actual and potencial volumes, derived from topographical profile levelling in situ and theory, respectively, for unity of the observed intertidal surface, and in a certain period of the annual cycle. This is expressed with the formula:

$$S.S.C.I. = \frac{Cr - Cp}{Su}$$

in which:

Cr = actual volume
Cp = potencial volume
Su = observed surface

The theoretical topography is calculated based upon the slope, obtaining:

a) In agreement with:

- the median diameter and densities of the beach sand,
- and the surf characteristics.

Formulas of the type of Sunamura (1984) are considered.

b) Or by employing empirical curves of the equilibrium between beach-face slope and the median diameter of sand.

Among others, Bascom (1959), Komar (1976), and Martínez (1986) describe curves of this type.

Using this method the estimation error is larger.

The potential volume for the operative total of a sandy beach, are deduced, in immediate form, with the equation:

$$Cp = L\ A\ (H - \frac{A}{2} \text{tag } a)$$

in which:

Cp = potential volume
L = operative length of the beach
A = amplitude of the observed strand
H = average vertical length from the head of the profiles till reference basis
a = beach - face slope.

The index in question qualifies the beaches according to:

- equilibrium,
- deficiencies
- or in surplus,

as is shown in table 2.

INDEX OF SEDIMENTARY VARIABILITY (S.V.I.)

This index is defined as the estimate of the average altitude of erosion to accretion, in an annual cycle, that overtakes the surface of an intertidal delimeted strip, in a sector of or in all of the beach. To sum up, it evaluates the maximum "effective" sedimentary deposition during the annual cycle under study.

In the calculation of this index:

- for a determined transverse profile, with a convenient length and width,
- or for the whole of the intertidal delimited strip of the beach;

we divide the volume of the sand into increments, during the period of significant accretion, for the basic profile section area, or for the operative strip.

The index of sedimentary variability qualifies the beaches as:

- changing attenuatedly (with low indices),
- changing moderately (with intermediate indexes)
- or changing strongly (with high indices),

as shown in table 3.

This index allows us to represent the longitudinal topographic movements of the beaches quantitatively, in scale block diagrams.

A third index that may be fundamental in temporal series analysis of the strand volumes, with data from successive campaigns during a significant number of years under study. The beaches are classified as stable, hyper-stable, and unstable, after the work of Suárez Bores (1980).

All of these indices need to be considered:

- in the design of projects, for the optimization and recuperation of sandy beaches,with maritime works and/or artificial sustenance,
- and in the continueing analysis of these beaches, when we have already had experience with the same, for verifying the conduct of the sedimentary process, and to adapt, in each case, the necessary corrective measures.

RESULTS

Table 4 shows the sand gains, in cubic meters, of the beaches under stu

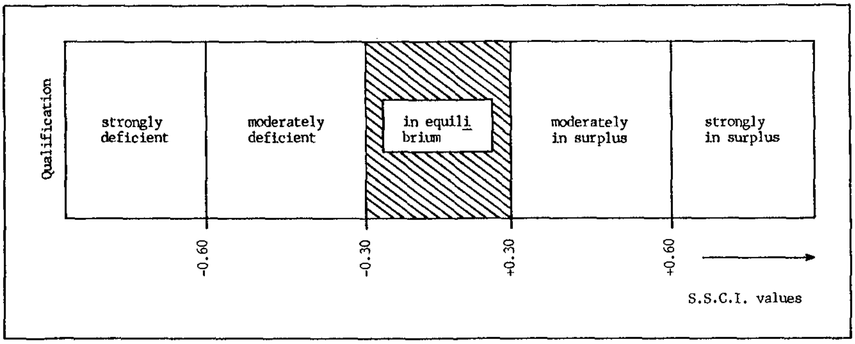

Table 2

Tentative scale for qualifying the sandy beaches according to the index of sedimentary support capacity.

S.V.I. values	Qualification
of 0.00 to 0.75	changing attenuatedly
of 0.75 to 1.50	changing moderately
> 1.50	changing strongly

Table 3

Tentative scale for qualifying the sandy beaches, according to the index of sedimentary variability.

Date \ beach	Sardina del N	Las Canteras	El Hombre	El Burrero	El Inglés	La Bajeta	Maspalomas
	Sand gains, in m³, in relation to the significant erosion of the annual cycle under study						
	D:66.8x9.0	D:2169.0x10.0	0:200.6x10.0	D:97.1x12.0	0:2111.0x15.0	D:471.5x15.0	0:2102.5x15.0
1985/12	303.14	05745.23	3285.30	689.49	32642.96	10680.09	04192.74
1986/1	272.50	03816.09	3585.86	334.70	35704.79	12365.50	06562.86
1986/2	038.38	04095.64	2893.17	313.86	40266.28	12024.72	00000.00
1986/3	100.58	00000.00	0271.30	300.93	38369.33	13671.17	01729.70
1986/4	000.00	03511.69	0000.00	166.31	35401.32	12476.15	01829.60
1986/5	070.63	05861.03	2779.44	292.80	29423.33	11574.44	04696.84
1986/6	266.69	09953.13	3434.31	251.82	17331.43	10148.07	14806.72
1986/7	494.01	09075.08	2686.86	226.63	16042.21	06671.15	16841.51
1986/8	489.18	10687.70	2959.49	132.51	14070.81	04225.79	28591.80
1986/9	327.72	09794.63	3192.79	091.71	12653.42	05070.47	30345.58
1986/10	444.91	04845.50	3096.40	000.00	08796.16	04499.33	37778.00
1986/11	343.37	---	3347.16	023.23	01338.24	02208.58	28671.13
1986/12	445.95	---	3051.68	---	00000.00	00000.00	10215.95

D = dimensions, in meters, of the intertidal delimited strip

Table 4

Sedimentary balances, during an annual cycle, in various sandy beaches on the island of Grand Canary (Spain).

dy, in relation to the most extreme erosion of the same. This corresponds to an annual cycle (1986).

In the Canaries are presented, habitually, certain surface meteorological situations. These form three groups, depending on the prevailing wind direction:

1. Atlantic anticyclones (trade winds), in combination with the occasional influence of Saharic thermal depressions, during the spring and summer. These involve winds from the N-NE.
2. Deep Atlantic storms with a nucleus over the Gulf of Vizcaya, and at times Atlantic anticyclones greatly displaced to the south, during the autumn and the end of winter-beginning of spring. These involve winds from the W-NW.
3. North-african and South-european anticyclones, Saharic thermal depressions, and Atlantic storms displaced to the south, from autumn to the beginning of spring. These involve winds from the E-S.

In figure 2 are recompiled the directional components and the frequency of these winds, depending on the aforementioned situations, that provoke the dominant and prevailing surfs on the Canary Island coasts.

In the selected beaches. The values of the sedimentary indices are recopied in table 5.

DISCUSSIONS

1. The beaches of Grand Canary are classified based on:

- their geographical location
- and the seasonal incidence of the surf.

We propose the fallowing groups:

Group I:

- beaches in the north cornice, under the influence of diffracted trade wind surf (from the N-NE), and exposed to storms from the W-NW,
- beaches of the south, protected from the trade wind surf.

Group II:

- beaches in the north cornice, directly exposed to the trade wind surf,
- beaches on the east coast, exposed to the trade winds.

Group III:

- beaches on the east coast, protected from the trade winds and open to the SE.

Group IV:

- beaches on the west coast.

We would like to present these transitional cases.

Beach	Period under study	S.S.C.I. (accretion)	Qualification	S.V.I. (annual)	Qualification
Sardina del N. (Galdar)	1985-86	-0.13	in equilibrium	0.82	changing moderately
Las Canteras S. (las Palmas)	1985-86	+0.15	in equilibrium	0.84	changing moderately
Playa Chica (Las Canteras)	1985-86	+0.24	in equilibrium	0.62	changing attenuatedly
Las Canteras N. (Las Palmas)	1985-86	+0.46	moderately in surplus	0.58	changing attenuatedly
El Hombre (Telde)	1985-86	+0.01	in equilibrium	1.79	changing strongly
El Burrero (Ingenio)	1985-86	-0.01	in equilibrium	0.59	changing attenuatedly
El Inglés (S. Bartolomé)	1985-86	+0.89	strongly in surplus	1.27	changing moderately
Punta de La Bajeta (S.Bartolomé)	1985-86	+0.74	strongly in surplus	1.93	changing strongly
Maspalomas (S.Bartolomé)	1985-86	+0.20	in equilibrium	1.20	changing moderately

Table 5

Estimations of the sedimentary support capacity and of the annual intertidal sedimentary variability, in various beaches under study in the Grand canary environment.

2. The significant accretions and erosion (table 4) of the beaches under study, inside of a yearly cycle, have a strong dependence on the proposed beach groups.

In the Group I sandy beaches the erosion takes place preferably during the winter and spring months, and the accretion during the summer and the first part of autumn.

In the Group II beaches the erosion culminates in summer, and the maximum accumulations occur at the end of autumn-beginning of winter.

In the Group III beaches the erosion develops, above all, during autumn, while the accretion takes place from the end of autumn until the beginning of spring.

The Group IV beaches are under actual study at this time.

Figures 3 and 4 show the performance described.

3. At this time we establish a correlation between:

- The most frequent of the different surface winds (figure 2), corresponding to the period of taking the beach data.
- The greatest probability of presentation and the highest maximims, to indefinite deph, of the surf in relation with these winds (with data from visual observations of ships en route).
- And the significant erosion processes in the beaches open to the surf in question (table 4).

In the correlations:

a) During the dominant time of the trade winds, in the summer, we see the greatest probability of the presentation of the "swell" surf from the N-NE.

In this period, and in the north, east and suthern coasts, predominate,- with various exceptions, wave heights between 1.83 and 3.66 m. Also are presented, although in low percentages, waves with heights greater than 3.66 m.

b) On the north coast, the maximum probability of the presentation of the "sea" surf, from the N-NE, coincides with the dominance of the trade winds. In this case the dominant waves are of little height, less than 0.91 m. They do not surpass a height of 2.44 m.

c) On the east and southern coasts, the maximum probabilities of the presentation of the "swell" and "sea" surfs from the E, SE and S take place during the autumn and winter and coincide with the most frequent winds determined by:

- South-european or North-african anticyclones,
- Saharic storms,
- or Atlantic storms displaced to the south.

The "sea" surf from the NE does not depend on the trade winds, but on the first two meteorological conditions mentioned above.

In this period waves of low height are predominate; smaller than or equal to 1.83 m. With the exception of "sea" surfs from the NE, they do not ap proach 3.66 m.

d) When the winds come from the W-NW, from autumn to spring, we observe the maximum probabilities of the presentation of the "swell" and "sea" surf from the NW.

During this period prevailing waves of heights between 1.83 and 3.66 m., and a few others that are higher, come to the nothern coast, which is directly affected.

4. In agreement with the described previous aspects, the physical model of the accretion - erosion processes, designed for the sandy beaches of Grand Canary, is formulated as fallows:

a) When the trade wind surf predominates and takes its main energy (in the summer season).

- This produces the most extreme erosion in Group II beaches.
- And develops the most important accretions in Group I beaches.

b) During the decline of the trade winds:

- The Group II beaches attain the process of accretion (autumn-winter).
- Surfs from the E,SE, and S make their appearance. The dominant and most energetic of these, in autumn, are connected with Group III beach erosion.
- And the Atlantic storms come from the W - NW (from autumn to spring). These same do not impede the most important accretions in the Group III beaches (winter) and determine, in those situations of high surf energy, the significant erosion in the Group I beaches (winter-spring).

5. The index of sedimentary support capacity qualifies for all the beaches under study between in equilibrium and strongly in surplus (table 5).

Forthwith, aside from anomalous very energetic oceanographic situations, and if we do not wish to enlarge the surface in use, the beaches do not have the capacity to accept artificial sustenance for the optimization of these sedimentary environments.

6. The annual sedimentary variations of the beaches are adjusted by a continuity function:

- the "net" processes of erosion are determined by the seasonal impact energies of the surf,
- and the "effective" sedimentary contributions (predominately gains over losses) occur when these impacts subside.

With respect to the dominant trade wind surf, the exposed beaches under study (El Hombre and Punta de La Bajeta) have higher indices of sedimentary variability than the protected ones (Sardina del Norte, Las Canteras, El Burrero, El Inglés and Maspalomas), as we see in table 5. The first group takes the title of "attenuating" and "moderately changing" while the second group takes the title "strongly changing".

From this we deduce that, on the island of Grand Canary, the surf from the N-NE is the most erosive in relation to the others.

On a single beach (Las Canteras for example), the sector most exposed to the indicated surf shows the largest sedimentary variation (Las Canteras South).

In a single beach or a sector of the same, with an important annual sedimentary variation, the construction of an adequate breakwater, nevertheless determines a reduction in the contributions, would produce a considerable reduction in the erosion processes. The result of the above conveys a net sand gain, with consequent growth of the dry-intertidal area.

CONCLUSIONS

The Grand Canary beaches are classified into four groups. For this we take into account:

- their geographic location,
- and the seasonal incidence of the surf.

The annual accretion and erosion processes are different for each beach group.

In the analysis of the sedimentary balances, we satisfactorily establish correlations between the selected significant variables.

The beaches under study are situated, for the one part, between in equilibrium and strongly in surplus, and for the other part, between attenuating and strongly changing, depending on the scales proposed for the sedimentary indices here defined.

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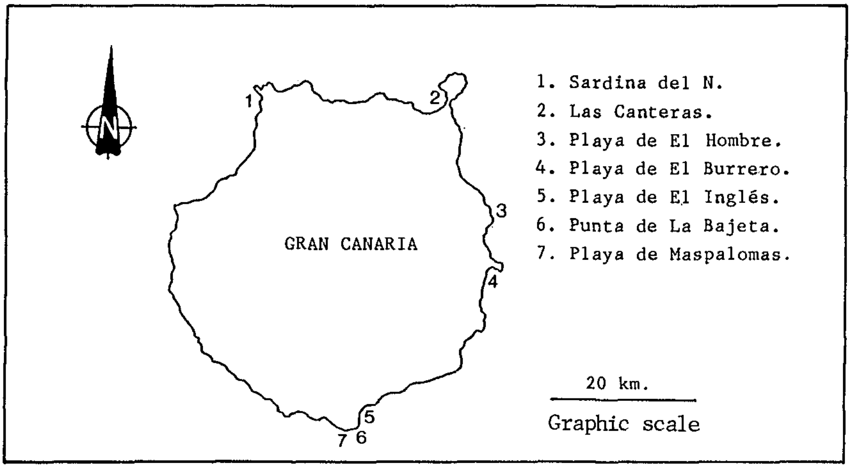

Figure 1

Geographical location of the Grandcanary beaches under study.

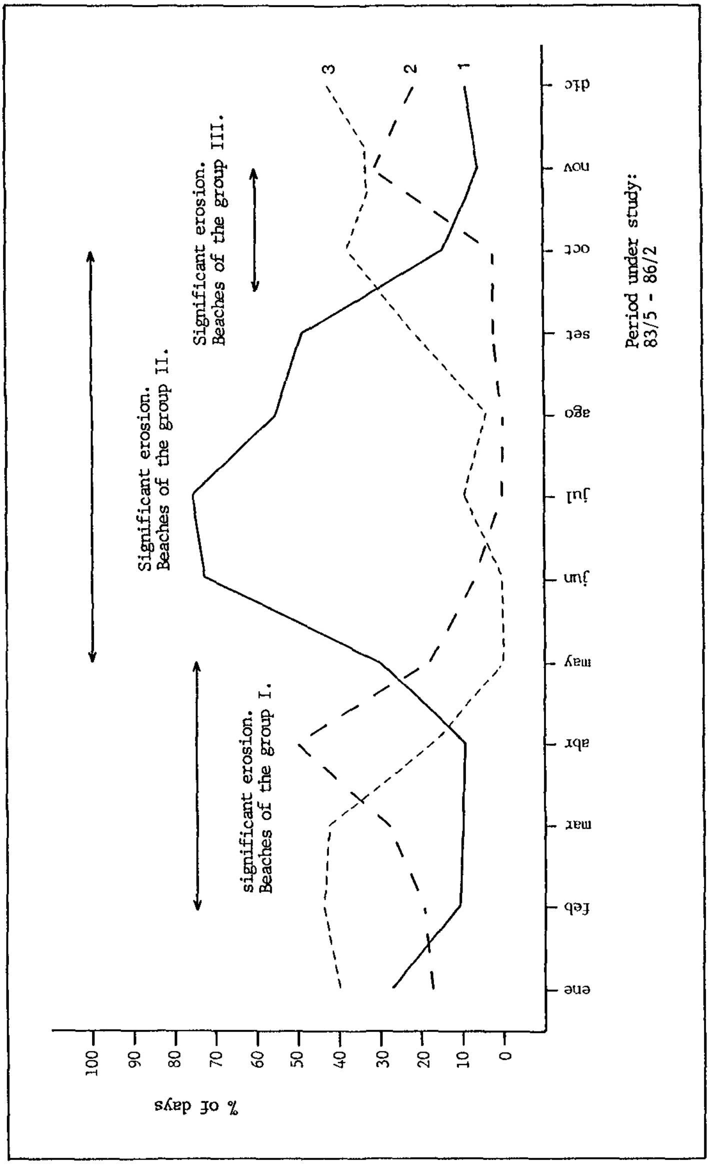

Figure 2

Frequency of the winds in the environment of the island of Grand Canary (Spain). 1: winds from the N - NE,, 2: winds from the W - NW,, 3: winds from the E - S.

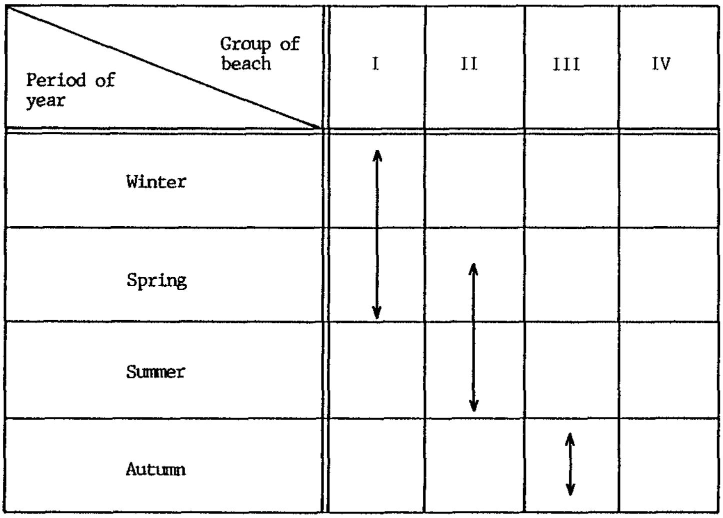

Figure 3

Localization of the extreme processes of annnual erosion in the sandy beaches of Grand Canary.

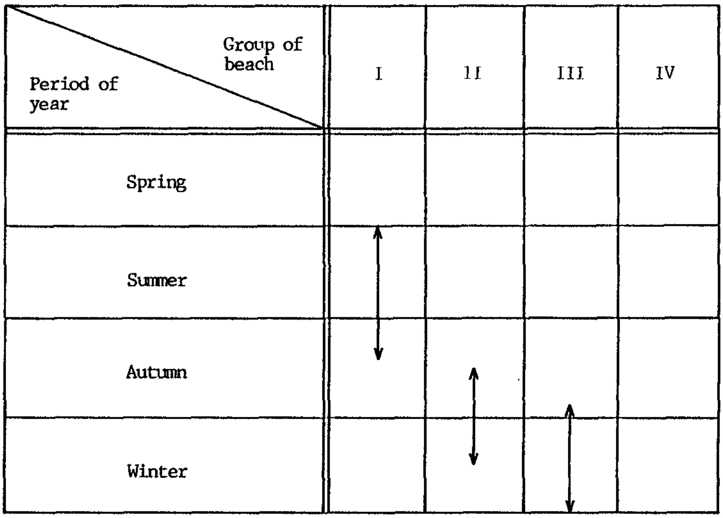

Figure 4

Localization of the most important annual accretion processes in the sandy beaches of Grand Canary.