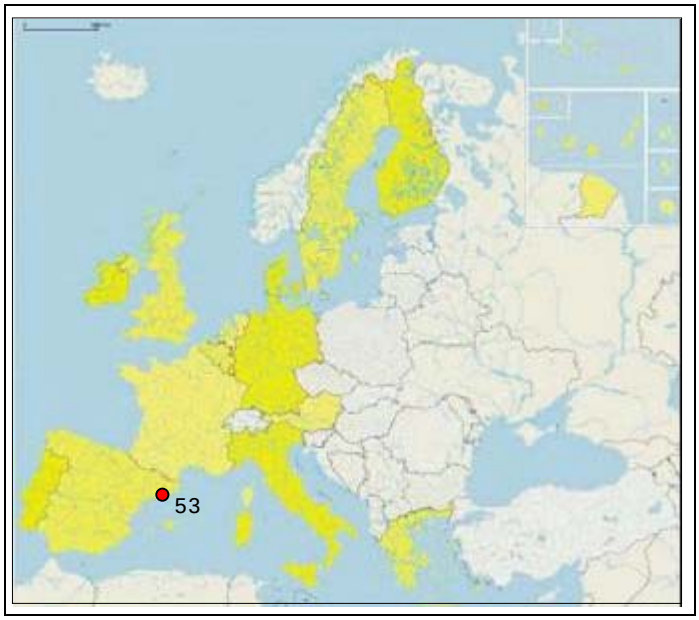
SITGES
(SPAIN)



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1. GENERAL DESCRIPTION OF THE AREA

The town of **Sitges** is located at the Mediterranean coast in Catalonia, an autonomous region in the northeast Spain, 40km south of Barcelona. Sitges has a coastal stretch of approximately 19km, which is made up of rocky coast and sandy beaches. There are 18 beaches in the municipality's coastal area, of which 10 are in front of the urban area The study area is located at the urbanised coastal area (see Figure 1).

Fig. 1: Aerial photograph's composition of Sitges coast.

1.1. Physical process level

1.1.1 Classification

- General: sand beaches, cliffs
- CORINE: rocky coast, beaches
- Coastal guide: coastal plain (recent sedimentary), cliffs

1.1.2 Geology

Sitges town is located in a Quaternary depression between the calcareous Garraf Massif. The calcareous rocks that form the rocky coast are similar than Older Mesozoic formations. Above sandstones and conglomerate it sets limestones and dolostones of Upper Triassic. The coastal plain is made up from alluvial materials (gravel, sand and clay) over the Mesozoic and Neogene formations. Beach and bottom sediments are of siliciclasthic origin and have a light gold colour. The sand grain size is fine to medium (D_{50}=0.166-0.205).

1.1.3 Morphology of the coast

Sitges town is located just in the north part of the coastal plain, between two calcareous bodies of the Garraf massif, in which forms a bay. The coastal stretch has a ENE-WSW direction, and the nearshore seabottom of the bay has a regular and low gradient slope, between 0º and 5º (see Figure 2).

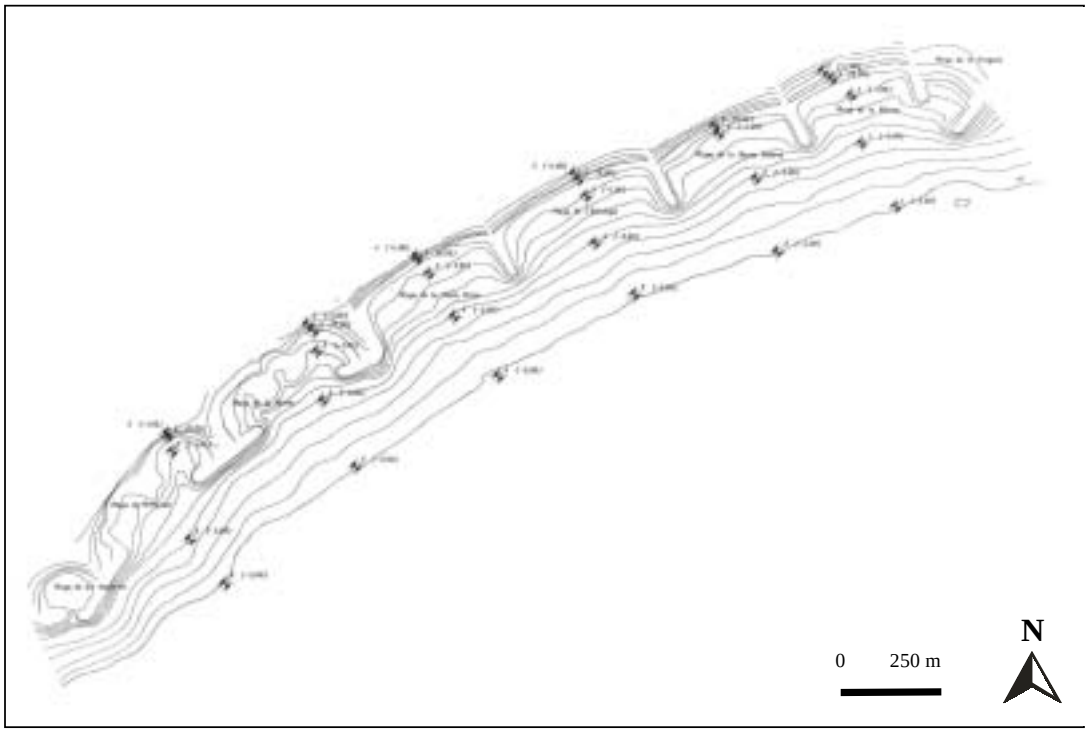

Fig. 2: Bathymetry of Sitges town seafront - from 1m to –5m (ALATEC, 1999).

1.1.4 Physical processes

The most common winds in Garraf coast are from NE, SE and SW directions, but the most energetic is the east wind, associated to storms. The wave climate is from E to SW directions. The storms are frequent in autumn and winter seasons and often erode significantly the beaches of the Catalan coast. These are the most powerful driving forces related to acute coastal erosion in the Catalan coast.

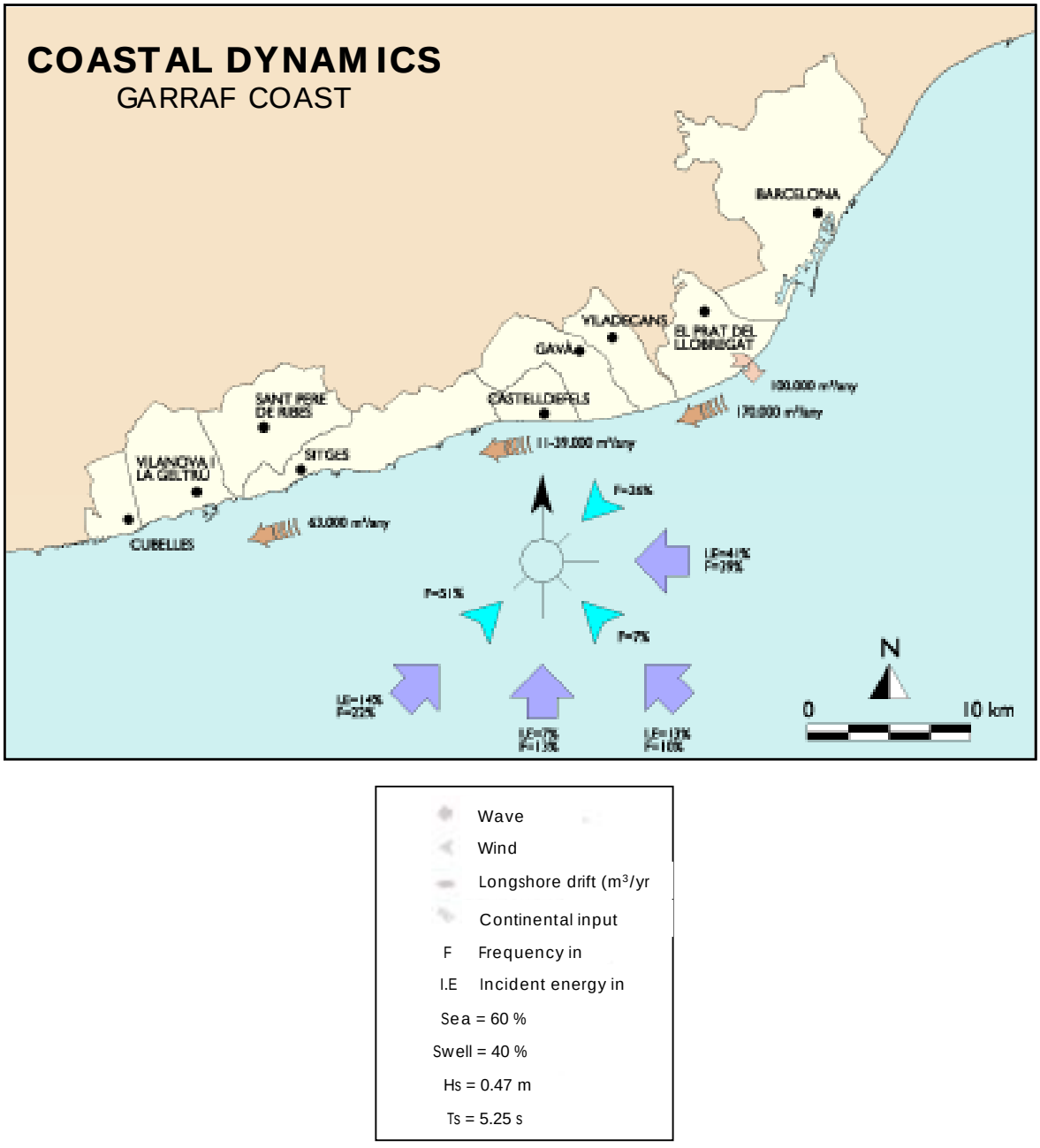

Fig. 3: Coastal dynamics of the rocky Garraf coast (Acebillo, 2000).

The Sitges coast has a microtidal regime, less than 20cm of maximum amplitude of oscillation and a semidiurnal period. There is a predominant longshore current along Catalan coast which flows to SW. The approximate mean transport of the longshore drift in this coast sector of Sitges is around 60,000m^3/yr (see Figure 3), being less than the needed for the natural feeding of beaches. The trend of sea level rise can be assumed of the same rate for the whole NW Mediterranean coast, at an average of 2-6mm/yr.

1.1.5 Erosion

The Garraf coast is experiencing since many decades a continuous structural erosion, sometimes increased by storm events which produce local and acute shoreline backward movement. The continuous decrease of the sediment input to the Garraf coast from the Llobregat River northly (due to dams and quarries), and the deviation of the longshore drift due to marinas, lead to an increase of erosion in Sitges beaches. The most important contribution to the sedimentary balance of Sitges beach comes from the Llobregat river, with a sediment input of 100,000m^3/yr. The sediment output is related to rip currents that transport the sediment to the offshore.

The interruption of the supply of new sediment carried by longshore drift has been the main factor leading to the loss of sand, however the occupation of the dune system by the urban area and the promenade which rigidez the seafront, preventing the auto-regeneration of the beach.

No data of erosion rates exist at the moment but there is an observed trend of beach width decrease to the south-west. Some estimations about decrease in beach surface were done (ALATEC, 1999) based on an analysis of aerial pictures comparing the dry beach surfaces calculated between them (see Table 1 in Chapter 2.1). These estimations can reflect the trends in erosion but not rates.

1.2. Socio-economic aspects

1.2.1 Population rate

The population density of Sitges is 378 inhab/km^2 (in 1996). Since 1975 the population of Sitges grew from 11,000 inhabitants to 20,000 in 2001 (see Figure 4).

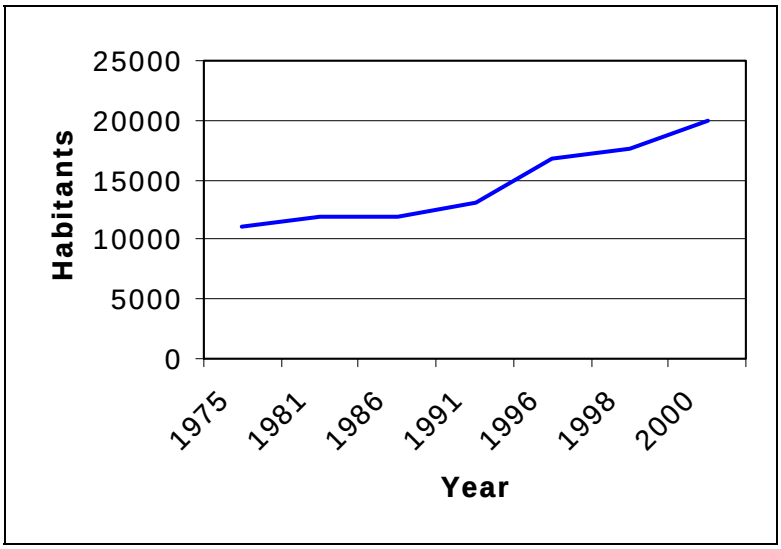

Fig. 4: Population evolution in 1975-2000 (Idescat, 2002).

1.2.2 Major functions of the coastal zone

- **Industry:** the present economy relies on tourism and industry. The latter of this two aspects is highly varied, with a particular large dependence on construction materials. This is physically located on the Garraf coasts where there are numerous quarries and the cement factory that forms the nucleus of Vallcarca.

- **Urbanisation:** the tourism explosion in the 20th century inspired a boom of urban expansion that came with very little ordered planning. This intense urbanisation has led to heavy pressure on the environment.

- **Ports and ships:** there are 4 ports on the Sitges coast: 3 marinas and 1 industrial port, all under jurisdiction of the Generalitat de Catalunya (regional government). In 2000 were recordered occupations from 62-78% in the 3 esportive marinas, which in total have a capacity for around 2,400 boats.

- **Tourism and recreation:** the town of Sitges has become an affluent tourist resort for the whole year round. This has led to the construction of a large number of houses and chalets that serve as second residences or holiday homes.

1.2.3 Land use

Urban areas, industry, natural areas, camping, agriculture, golf field.

1.2.4 Assessment of capital at risk

The disappearance of sand in the beaches of Sitges has a direct effect, which is the Association of Concessionaires of the Beaches of Sitges. This group is made up of 44 concessionaires of the shade, hammock, and beach bar services. Therefore, the reduction of the surface of the beach is directly related to these economic activities and the hundred or so people involved.

2. PROBLEM DESCRIPTION

2.1. Eroding sites

All Sitges town beaches (except Balmins, Sant Sebastià and Fragata) suffered from chronic erosion. Recent monitoring of Sitges beaches shows the important erosion at Riera Xica, Barra and Terramar beaches produced by frequent storms. The following table demonstrates the loss of beach surface in Sitges urban area beaches since 1966.

Table 1: Historical evolution of emerged beach surface (in m^2) before 1995. Beaches from northeast to southwest - Sitges urban area (ALATEC, 1999).

Beach / *Date of aerial flight*	**Balmins**	**San Sebastián**	**Fragata**	**Ribera**	**Bassa Rodona**	**Estanyol**	**Riera Xica**	**Barra**	**Terramar**	**Anguines**
7/1966	300	5000	13100	18200	9100	8100	4400	2100	5400	9800
9/1970			11400	15000	9600	9000	5900	4200	6100	9700
11/1975			11200	14200	9400	11100	6900	4100	5800	9600
2/1980			11600	13300	7400	9500	4500	3700	5300	8500
7/1990			12200	10170	7000	9800	4600	11600	10700	9000
9/1991	2200	5400	13100	9700	6800	9400	4600	12200	9600	9600
¿?/1995	5800	5400	12200	9600	5300	8900	4800	14700	11400	8500

2.2. Impacts

The major impact of the erosion is the loss of beach surface. Sitges economy depends basically on tourism, and mainly summer tourism. The beach losses are the main worry for all the stakeholders involved. Another impact derived from the loss of beach surface is the threatening of the beach promenade, the image of the town.

3. SOLUTIONS / MEASURES

3.1 Policy options

The policy adopted by the Spanish government for coastal protection in the case of Sitges is to ***hold the line***. Coastal defence actions become necessary to protect the beaches from erosion and to maintain their quality.

3.2 Strategy

The coastal policy developed by the set of public administration until the drafting of the present Shore Act was dedicated almost exclusively to developing hard type defences, without considering the planning and management of the coast, and only responding to the economic interests of the local administrations relation to urban growth and tourism. With the Shore Act of 1988, the strategy changed to the use of softer measures like the beach nourishment.
This evolution has been observed in the Sitges where, several hard measures were built before 1988 when the act came out.

Issues concerning threats to life and property are focused in several laws at a national, regional and local level. The Civil Protection Act, approved by the Government of Spain in 1985, is the main guideline for action in the case of natural disasters (national level). Another measure at a regional level is the Civil Protection Plan of 1997, made by the Generalitat de Catalunya (regional administration). On the Catalan coast, the most common causes activating the Civil Protection Plan are storm events, which are frequent between September and July. The streams along Catalan coast behave violently and unpredictably because of their short time and high intensity of response, and most urban areas on the Maresme and Garraf coasts were built upon river floodplains.

3.3 Technical measures

The measures adopted for Sitges case are both *hard measures*, such as groins, detached breakwaters, T-shaped breakwaters, artificial islands and seawalls, and *ft measures*, such as beach nourishment.

The historical evolution of the shoreline protection actions in Sitges town can be resumed as (Table 2):

Table 2: Historical evolution of Sitges coastal protection (ALATEC, 1999).

2 groynes	1930	Delimitation of Anguines beach
2 groynes	1947-1948	Delimitation of Fragata and Ribera beaches
Seawall	1950	Seawall in old town seafront, remodelation of groynes
Seawall	1955	Terramar beach
1 groyne	1959	Delimitation of Ribera and Bassa rodona beaches
3 groynes	1970	Between B.Rodona and Anguines beaches
Seawall	1975	Bassa Rodona beach
Nourishment T-shaped breakwaters Detached breakwaters	1984	Remodelation of Barra and Terramar groynes; sand nourishment of both.
Nourishment	1985	San Sebastià beach
Nourishment	1991	Balmins beach
Nourishment	2002	Estanyol, Riera Xica, Barra and Terramar beaches

Beach nourishments of 1984 consisted on 34,700m^3 of sand dredged from Vilanova i la Geltrú, southwest of Sitges town. The last performance of nourishment has been done in July 2002 in Estanyol, Riera Xica, Barra and Terramar beaches, and consisted of a sand filling of about 50,000m^3 dredged from Port Ginesta marina and cost about 480,000€.

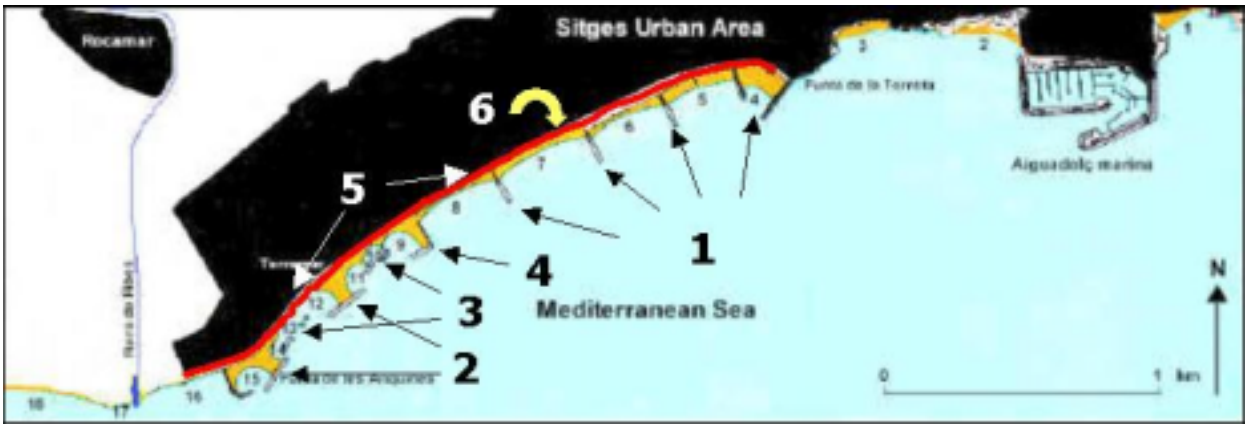

Fig. 6: Map of location of coastal defence structures of Sitges urban area. See photos below.

Fig. 7: Groynes (nº1)

Fig. 8: Detached breakwaters (nº2)

Fig. 9: Artificial islands & t-shaped breakwater (nº3-4)

Fig. 10: Seawall (nº5)

Fig.11: Sand replenishment (nº6)

Fig. 12: Sand replenishment works (nº6)

4. EFFECTS AND LESSONS LEARNT

4.1 Effects related to erosion

The construction of the marine promenade at Sitges caused the fixing of the coastline, from which a whole set of impacts was derived. The promenade became a rigid artificial barrier to the natural outlet of the several torrents that crossed the zone (today transformed into streets), leading to frequent flooding. The promenade was constructed, altering completely the natural profile of the beach.

The hard defences adopted for the case of Sitges did not stop erosion processes existing at the moment. It is proven that they are not effective in the protection of the Sitges promenade, because several times after critical storms, the promenade has been repaired. Beach nourishment is a temporary solution because it is not directed to the main causes of erosion, but to diminish the consequences.

After the last beach nourishment operation in July 2002, a set of storms swept away a huge part of the freshly nourished sediments. (see Figure 13).

Fig. 13: Effects of the September 2002 storms in Barra beach. The scars were made by the river discharge. This beach was renourished in July 2002.

4.2 Effects related to socio-economic aspects

In terms of aesthetic impacts, the groynes caused compartmentalisation of the seafront, altering the visual field laterally, and the detached breakwaters caused an alteration of the horizon line. There is frequently an accumulation of rubbish in the corners of the groynes and breakwaters.

The beaches are regularly used for recreational activities like swimming, sunbathing, water sports, sports on the sand (volleyball, soccer), entertainments, etc. So, the beaches belong to the recreational areas of the town and have an important social function, as well as being the income source for tourism and recreation activities. The reduction in the beach surface directly affects this social use, and therefore the user, as regards comfort and the variety of uses.

4.3 Effects in neighbouring regions

The numerous groynes retain the sediments that circulate in a NE-SW longshore drift and avoid the feeding of the western beaches (Estanyol, Riera Xica, Barra, Terramar and Anguines), worsening the problem of erosion in these areas.

The marina docks deviate offshore a huge part of the sediment load carried by longshore drift. This problem is especially worrying in the Maresme coast, north of Barcelona. The effects of reduced sediment input plus hard defences caused in the Maresme coast the loss of a high part of sediment in beaches, which again lead to continuous beach nourishment operations.

4.4 Relation with ICZM

The responsibilities in the coastal zone are taken by the Ministry of the Environment (General Directorate for Coasts) and the Ministry of Public Works. By the Shores Act of 1988, the Spanish government regulate the development on the coastal strip by progressive delimitations of the coastal public domain. The Ministry of Public Works is the responsible of the coastal defence actions in the country.

A national ICZM policy does not exist in Spain.

One of the points of interest in Sitges beaches is the quality of them. The town has currently the award of "Blue Flag" given by the European community in most of its beaches (http://www.blueflag.org/Map_Spain). Actually all the coastal defence schemes need to have an environmental impact study, which includes the quality of the beach.

4.5 Conclusions

Effectiveness

- The hard defences are proven inefficient and very expensive Need more maintenance.
- Nourishments are only a temporary solution.

Possible undesirable effects

- The impact of the dredging operations on the seagrass communities (*Posidonia oceanica*).
- Aesthetical impact of the groins and breakwaters.

Gaps in information

- Dispersion of information among different institutions.
- Lack of a long time series for collecting the data. Makes difficult build predictive models.
- Heterogeneous data.
- Historical studies are the result of individual contributions, concentrated in space and time.

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