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Application of the DPSIR model to the Sado Estuary in a GIS context – Social and Economical Pressures

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SUMMARY

Find the more appropriate tools that help to assess and manage the estuarine environments, allowing their restoration, is one of the main issues in coastal zone managements. This paper describes the application to an estuary in Portugal of the indicators framework DPSIR - Driving Forces-Pressures-State-Impact-Response in a Geographical Information System (GIS) context. The focus of this work was done to the first two categories. Within the Sado Estuary, Setúbal sub-watershed was chosen as the case of study and a set of indicators for the Driving Forces and Pressures categories was defined, and the indicators calculated and discussed.

KEYWORDS: *Sado estuary, DPSIR Model, GIS, Indicators*

LONG ABSTRACT

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SUMMARY
Find the more appropriate tools that help to assess and manage the estuarine environments, allowing their restoration, is one of the main issues in coastal zone managements. This paper describes the application to an estuary in Portugal of the indicators framework DPSIR - Driving Forces-Pressures-State-Impact-Response in a Geographical Information System (GIS) context. The focus of this work was done to the first two categories. Within the Sado Estuary, Setúbal sub-watershed was chosen as the case of study and a set of indicators for the Driving Forces and Pressures categories was defined, and the indicators calculated and discussed.

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INTRODUCTION
The DPSIR Model, adopted by the European Environmental Agency, is one of the frameworks based on the concept of causality chains for data synthesis, whish links environmental information using indicators of different categories (**Driving forces**, **Pressure**, **State**, **Impacts** and **Responses**) (UNEP/RIVM, 1994; RIVM, 1995). This model is similar to PSR framework (OCDE, 1993), but with two more categories: **Driving forces** and **Impacts**. The first reports to the "needs" of individuals and institutions that lead to activities that exert pressures on the environment. The "intensity" of the **Pressure** depends on the nature and extent of the **Driving forces** and also on other factors which shape human interaction with ecological systems. The **Impacts** are related on ecosystems and human well being due to **State** modifications. The policy responses lead to changes in the DPSIR chain. (Greeuw et al. 2001) stated that a key issue is that the same item can appear in different places in the framework, depending upon which target we are focusing on. Also according to (Kelly 1998), fails to capture the complexity of the relationships in complex systems (Ramos *et al.*, 2004). Nevertheless it is a model largely used and if these drawbacks are taken into account, it could work as a good tool to support the management of ecosystems. Also indicators are an excellent way of representing the environmental components avoiding the measurement of too many parameters. Indicators are often adopted to avoid and reduce the complexity of environmental data. In general, indicators are easily quantified and delineated from already described information in protective goods like environmental compartments and are adequate to assess what is called ecosystem health (Costanza, 1992).

The DPSIR framework can be used as a base for a coastal zone environmental management allowing the linkage between environmental and macro-economic models, making it possible to integrate the conservation functions (biodiversity and ecological) with socio-economic development (RIVM, 1995). The application of this causality models in a GIS context has the advantage of allowing the spatial visualization and better integration of the different indicators.

The use of these models of causality chains and the selection of the indicators has often been applied in coastal zone management in the last decades. Examples could be Cardoso da Silva, 1996, EEA, 1999a), 1999b), USEPA, 1999, ME, 2001, Casazza *et al*. 2002, Elliott, 2002, Piccolo *et al.*, 2003, Nunneri *et al.*, 2003, among others. However some of these approaches are only conceptual or little attention are paid to the difficulties of calculating the indicators and their spatial visualization and interpretation for future management of the coastal zones. This fact is of particular importance in the social and economic pressures indicators.

This paper illustrates the practical application of the DPSIR model to the Sado Estuary. This estuary, located in the South of Portugal, is an area where management conflicts are known: although it has a high ecological value, fact that is highlighted by the existence of a Natural Reserve, it is a very industrialized and populated zone. Therefore, it becomes necessary to build and implement environmental assessment models, which include the construction of methodologies and frameworks that, quantitatively and qualitatively, define the state of coastal area and point out management options.

The main aim of the research project in which this work is included is to produce new and specific data through a GIS as the base for the development of a methodology for the Sado Estuary environmental management system using the DPSIR model. This paper describes the preliminary results of a quantitative approach of indicators set of the first two model categories- **Driving forces** and **Pressures**. One of the Sado's river sub-watersheds was used as example.

METHODOLOGY

Previous Work

The methodological approach of this research project is briefly described in Figure 1. Collection of information about conceptual frameworks for indicators and compilation of all kind of data related to the Sado Estuary were the initial tasks of this research project. In Caeiro *et al.*, 2003 it is presented an overview and discussion about the different indicator frameworks available in literature. When the DPSIR model was elected as the assessment tool one preliminary set of indicators for each of its components was selected (Caeiro *et al.*, 2002).

The methodology proposed for the environmental management system applied to Sado Estuary supported on the DPISR framework, is based on identifying, representing and characterizing a series of homogeneous environmental areas inside the estuary (Caeiro *et al.*, 2003). On each of these management areas the indicators of the categories **State** and **Impact** are going to be quantified. These areas are then to be linked with the social and economic pressures (**Driving forces** and **Pressures** indicators) of the surrounding areas of the estuary.

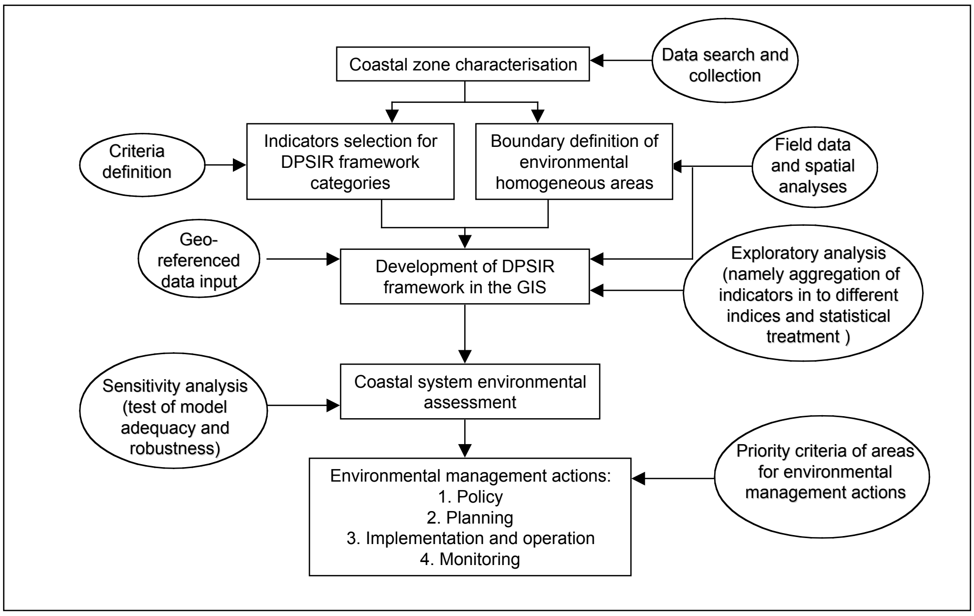

Figure 1: Methodology for estuary environmental management (adapted from Caeiro ***et al.***, 2002).

This management system will allow the integration between the biodiversity conservation and human pressure for development. The methodological approach to integrate this information will be the implementation of a GIS.

Driving Forces and Pressures Evaluation

..After the selection of the **Driving forces** and **Pressures** indicators their data was collected in the different institutions in Portugal (see Table 1). The GIS was developed in *ArcMap 8.1*.

The GIS was simultaneously a mean to visualize data and a calculation tool for indicators that were related to geographical information. Watershed areas were chosen as administrative units for indicators representation and Setúbal sub-watershed was elected as an example for the calculation of the indicators (
Figure ***2***). The higher social and economic pressures are expected in this sub-watershed. A range of normalizing factor was used to develop the environmental indicators like for example sub-watershed area, estuary area or coastline length. The estuary area considered was the main bay and the entrances of the Aguas de Moura and Alcacer Channels (about 110 km^2). This normalization allows the indicators comparison, including with other costal zones and also allows a better evaluation of the level of their magnitude.

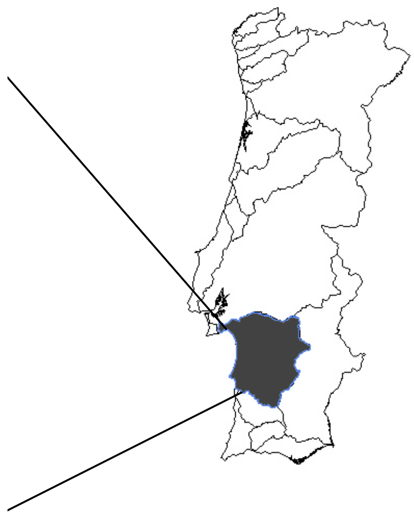

Figure 2: Sado watershed and Setúbal sub-watershed (adapted form INAG, 2001).

RESULTS AND DISCUSSION

The set of selected indicators that were chosen for the **Driving forces** and **Pressure** categories are listed in Table 1. The preliminary calculation and spatial representation of Table 1 indicators are described above. However, some indicators are not yet calculated or georeferenced due to not yet the unavailability of the data.

Table 1: Selected indicators, unit, GIS representation and source of information.

Driving Force Category	**Unit**	**GIS Representation**	**Source of Information**
Urban areas near the estuary	km^2	Area	Portuguese Geographical Institute (IGP)
Industry types	Number of establishment per industry	Point	Statistics National Institute (INE)
Dunghills/ sanitary landfills	km^2	Area	National Waste Institute (INR)
Rice-fields	km^2	Area	IGP
Salt-pans	km^2	Area	Sado Estuary Natural Reserve (RNES)
Aquacultures	km^2	Area	RNES
Fishing	number of ships. $year^{-1}$	Area	Ministry of Agriculture and Fishery (MAP)
Ships traffic	number of ships per harbour. $year^{-1}$	Point	Setubal and Sesimbra Administrative Port (APSS)
Harbours	number	Point	APSS
Tourism areas	km^2	Area	Statistics National Institute (INE)
Pressure Indicator	**Unit**	**GIS Representation**	**Source of Information**
Population density	$inhab.km^{-2}$	Area	INE
Toxic substances spill	Number of spills occurrence. $year^{-1}$	Point	Maritime Police
Pesticides in rice-fields	$t.ha^{-1}.year^{-1}$	Area	Technical / scientific papers
Fertilizers in rice-fields	$t.ha^{-1}.year^{-1}$	Area	Technical / scientific papers
Commercial species captured (fish and bait)	t fresh $weight.year^{-1}$	Area for fishery and point for bait	MAP
Dredging	$m^3.year^{-1}$	Point	APSS
Dredged material disposal	$m^3.year^{-1}$	Point	APSS
Urban wastewater discharges without suitable treatment	$m^3.year^{-1}$ or t contaminant. $year^{-1}$	Point	INE/INAG
Industrial wastewater discharges without suitable treatment	$m^3.year^{-1}$or t contaminant. $year^{-1}$	Point	INE
Solid waste disposal	$t.year^{-1}$	Area	INR
Solid industrial waste disposal	$t.year^{-1}$	Area	INR

Non source pollution (water runoff)	$t.year^{-1}$	Area	Water Institute (INAG)

Driving Forces Indicators

The **Urban Areas near the Estuary** indicator is represented in Figure 3. The urban use has an area of approximately 10,28 km^2, corresponding to 4.5 % of the sub-watershed total area, distributed in 11 villages (Table 2). This sub-watershed has a lot of urban areas since the main city (Setúbal) of the surrounding areas of the estuary is located in this sub-watershed. As can be noticed from the figure most of the larger urban areas are clustered and located just near the estuary boundary.

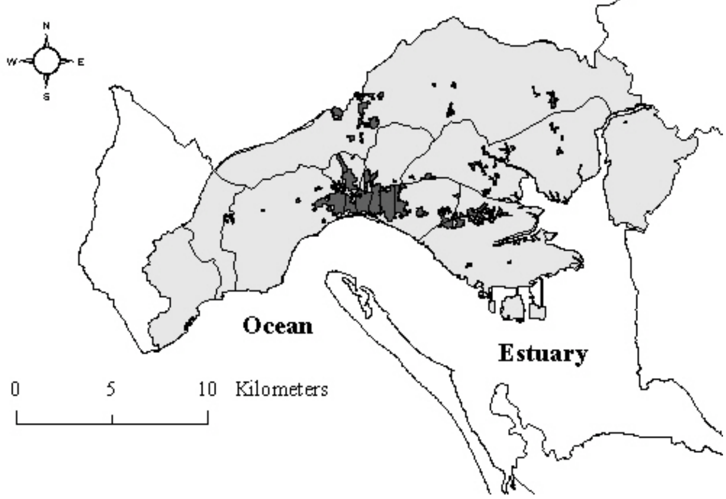

Figure 3: Urban land use area in Setúbal sub-watershed.

Table 2: Urban use in each village.

Village	Area (km^2)	% Setúbal sub watershed Area
Gâmbia-Pontes-Alto da Guerra	0.68	0.30
Marateca	0.01	0.00
Palmela	1.50	0.66
Sado	1.20	0.53
São Lourenco	0.06	0.03
São Simao	0.02	0.01
Setúbal (Nossa Senhora da Anunciada)	1.41	0.62
Setúbal (Santa Maria da Graça)	1.00	0.44
Setúbal (São Julião)	1.26	0.56
Setúbal (São Sebastião)	3.16	1.40
Total urban area in the sub-basin (km^2)	**10.28**	**4.55**

Source: IGEO, 2003.

The **rice-fields** area in the Setúbal sub-watershed is 4,18 km^2, corresponding to only 1.8 % of the sub-watershed area (fig. 4). The major rice-fields are located on the right side of the sub-watershed near the Aguas de Moura Channel. This means that the pesticides and fertilizes runoff into the estuary mainly through this channel.

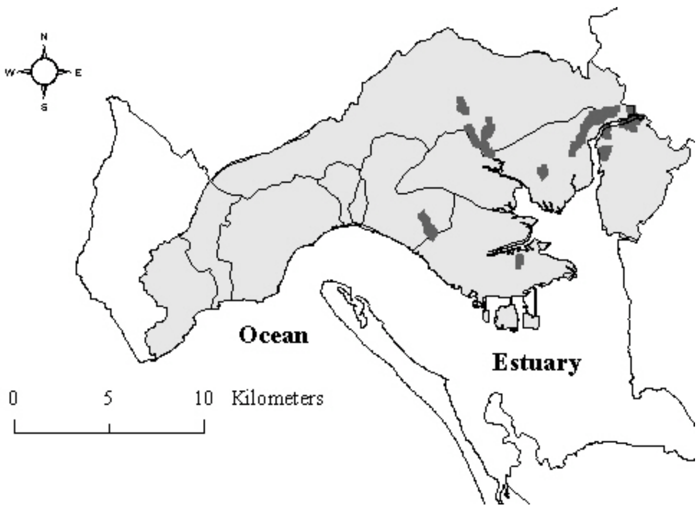

Figure 4: Area of rice-field in Setúbal sub-watershed.

Salt exploration in usually organized by groups (Dias, 1995) of **salt-pans** (Table 3). The sum of the area of this **Driving Force** is 8,36 km^2 corresponding to a total of 19 groups and 3.7 % of the sub-watershed area. This indicator should also be seen as a positive **pressure** since the maintenance of salt-pans is a signal of conservation and biodiversity.

Table 3: Groups of Salt-pan and their areas in the Sado Estuary.

Group	Area (km^2)	% sub-watershed Area
Faralhão	0.40	0.17
Gambia	0.61	0.27
Mitrena	0.22	0.10
Monte de Cabras	0.95	0.42
Mouriscas	0.52	0.23
Pinheiro Torto	0.19	0.08
Praias do Sado	0.97	0.43
Sachola	0.00	0.00
Vaia	0.70	0.31
Vale de Judeus	0.21	0.09
Batalha	1.00	0.44
Bocas de Palma	0.80	0.35
Cachopos	0.00	0.00
Comporta	0.08	0.03
Enxarroqueira	0.34	0.15
Faias	0.13	0.06
Monte da Pedra	0.58	0.26
Torrinha e Casas Novas	0.68	0.30
Total area (km^2)	**8.36**	**3.70**

Source: Dias, 1995

Since **aquacultures** frequently are implemented in old salt-pans (Dias, 1995) their groups are similar to the previous salt-pans (Table 4). This fact can cause difficulties in the spatial representation of this indicator (negative pressure) that needs to be distinguished from the previous indicator (positive pressure). Comparing Table 3 with 4 it can be noticed that some old groups of salt-pan areas disappeared to give place to aquacultures, in some cases with larger areas. This replacements and new installations are one of the concerns of the Natural Reserve since some of these aquacultures are working with no authorized intensive systems that can cause extra organic loads into the estuary.

Table 4: Aquaculture groups and their areas in the Sado Estuary.

Group	Area (km^2)	% sub-watershed Area
Faralhão	0.89	0.39
Gâmbia	1.10	0.49
Mitrena	0.32	0.14
Monte de Cabras	0.06	0.03
Mouriscas	0.12	0.05
Pinheiro Torto	0.09	0.04
Praias do Sado	0.36	0.16
Sachola	1.19	0.53
Vaia	0.47	0.21
Vale de Judeus	0.18	0.08
Batalha	0.00	0.00
Bocas de Palma	0.03	0.01
Cachopos	0.20	0.09
Comporta	0.00	0.00
Enxarroqueira	0.03	0.01
Faias	0.08	0.04
Monte da Pedra	0.00	0.00
Torrinha e Casas Novas	0.00	0.00
Total area (km^2)	**5.12**	**2.27**

Source: Dias, 1995

The number of **ships** that discharged in the fishing docks, for the period between 1998 and 2002, is listed in ***Table 5***. It can be noticed a decrease in the number of boats along these years in Setúbal dock, but an increase in the other docks in the year of 2002. In this last year the fish ships represented only 6 % of the total traffic of ships (Table 6).

Table 5: Annual number of ships that discharged in the fishing docks.

Fishing dock	Ships.y^{-1}				
	1998	1999	2000	2001	2002
Setúbal	355	318	318	318	277
Gâmbia	77	77	77	77	78
Carrasqueira	48	43	43	43	50
Total	**480**	**438**	**438**	**438**	**405**

Source: DocaPesca (MAP)

The **traffic of ships** per commercial harbour, during the period 1998-2003, is listed in Table 6. It can be previewed an increase of pressure in the estuary due to an increase of ships in the years of 2003 (about 60 ships per km^2 of estuary area per year), although not too much when compared with earlier years like 1999. Praias do Sado is the Harbour with higher traffic so higher impact in the estuary is expected in this area.

Table 6: Annual traffic of ships per commercial harbour.

	Ships.y^{-1}				
Harbour	1999	2000	2001	2002	2003 (Prevision)
Fountainheads	1291	1230	1268	1157	1240
Roll-on Roll-off	296	532	579	491	560
Multiusos	165	162	129	298	250
Cais nº. 10	134	307	222	180	200
Cais nº. 11	4	106	165	124	140
Eurominas	964	1058	295	-	-
Sapec	877	920	862	878	930
AutoEuropa	124	-	-	-	-
Eurominas	-	-	866	468	440
Tanquisado	438	453	597	575	650

	Ships.y-1				
Harbour	1999	2000	2001	2002	2003 (Prevision)
Alstom	5	12	25	28	20
Mauri-Fermentos	8	8	7	12	10
Praias do Sado	1621	1095	1254	1660	1605
Secil	638	546	417	534	470
Lisnave	1	12	22	9	25
Uralada	13	17	25	24	30
Ao Largo	1	1	7	7	5
Total	**6578**	**6459**	**6741**	**6444**	**6575**

Source: APSS, 2003

The major existing harbours of the estuary are located on Setubal sub-watershed. It has 20 **harbours**, most of them industrial. The area occupied by these structures is approximately 0,90 km^2 (Figure 5), which represents approximately half of the coastal line occupied by the sub-watershed, and 1,7 harbour per km of coast line.

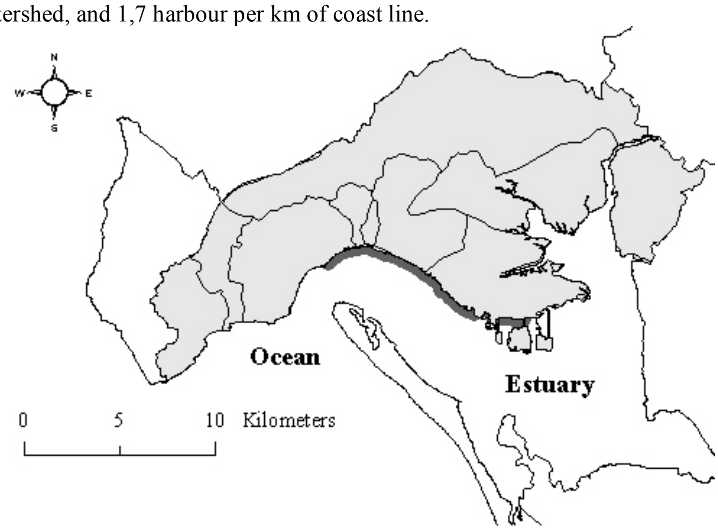

Figure 5: Area occupied by harbours in Setúbal sub-watershed.

Pressures Indicators

In the villages that belong to the Setúbal sub-watershed, the **population density** is presented in ***Table 7***. The higher densities are found in the Setubal villages, just near the estuary boundary.

Table 7: Population density in villages inside Setúbal sub-basin.

Village	**Population density ($inhab.km^{-2}$)**
Gâmbia-Pontes-Alto da Guerra	125
Marateca	27
Palmela	214
Rio Sado	-
Sado	142
São Lourenço	178
São Simão	214
Setúbal (Nossa Senhora da Anunciada)	587
Setúbal (Santa Maria da Graça)	7630
Setúbal (São Julião)	4107
Setúbal (São Sebastião)	2511
Total	**15724**

Source: INE, 2003

The **fish** tones discharged in the fishing docks located in the estuary are described in ***Table 8***. Setubal dock has not only the higher total number of fish discharged but also the higher fish discharged per boat. Along the years 1998 to 2002 there is an increase of commercial fish captured which should be compared with the fish stock to allow the evaluation of the impact in the estuary. Although the number of boats has not increase substantially during that period (Table 5) the total fish captured increase about 44 %.

Special care must be taken in the spatial interpretation of this indicator. A higher number of fish discharged in one of the docks does not mean a higher pressure on the fish stocks near the dock area. So the representation of these indicators should be done only in one global area where estuarine and marine fish are caught. This indicator is very important, nevertheless the available data do not allow knowing where are the areas of the estuary that suffer a higher captures effort.

Table 8: Annual fish fresh weight -weight discharged in Sado estuary docks.

Fishing dock	Captured fish fresh weight - $t.y^{-1}$ ($t.y^{-1}.boat^{-1}$)				
	1998	**1999**	**2000**	**2001**	**2002**
Setúbal	2474157 (6969)	3015106 (9481)	3466322 (10900)	3124695 (9826)	2575168 (9297)
Gâmbia	68114 (885)	38832 (504)	46523 (604)	86145 (1119)	183330 (2350)
Carrasqueira	69917 (1457)	52731 (1226)	66691 (1551)	70775 (1646)	86529 (1731)
Total	**2612188 (9311)**	**3106669 (11211)**	**3579536 (13055)**	**3281615 (12591)**	**2845027 (13378)**

Source: DocaPesca (MAP)

According to APSS the estimated total volume of **dredged** material will be 919,186 m^3 in the year of 2004 (Table 9). These dredging operations are related with maintenance of the navigation channel and will correspond to about 8 m per km^2 of estuary area.

Table 9: Location and volumes to be dredged.

Spot	Volume (m^3)
North channel	435,336
South channel	79,000
Barra	404,850
Total volume (m^3)	**919,186**

Source: APSS, 2003

This **dredged** material will be **disposed** in Canhão de Setúbal, an area outside the estuary with high hydrodynamics. Therefore, it is assumed that this activity will not exert pressure on the study system.

Urban wastewater discharges without suitable treatment were expressed in terms of load estimations, related to Biological Oxygen Demand (BOD), Nitrogen (N), Phosphorous (P) and Total Suspended Solids (TSS). These loads were calculated based on bibliographical information concerning emission factors per capita (Table 10) (Metcalf & Eddy, 1995), ***Figure 6*** shows the location of urban wastewater discharge points without suitable treatment. Two of the discharges points are located near the higher density locations and the industrialized zone and the higher pollution load comes from Sao Sebastiao village in city of Setubal.

Table 10: Daily and annual load estimations per village.

Village	BOD ($g.d^{-1}$)	N ($g.d^{-1}$)	P ($g.d^{-1}$)	TSS ($g.d^{-1}$)	BOD ($t.y^{-1}$)	N ($t.y^{-1}$)	P ($t.y^{-1}$)	TSS ($t.y^{-1}$)
Palmela	870264	145689	17566	1941978	317.64	53.18	6.41	708.82
Setúbal (Nossa Sr.ª Anunciada)	868968	145472	17540	1939086	317.17	53.10	6.40	707.77
Setúbal (Santa Maria da Graça	288360	48274	5821	643470	105.25	17.62	2.12	234.87
Setúbal (São Julião)	921780	154313	18606	2056935	336.45	56.32	6.79	750.78
São Lourenço	458298	76722	9251	1022684	167.28	28.00	3.38	373.28
Setúbal (São Sebastião)	2851956	477439	57567	6364087	1040.96	174.27	21.01	2322.89
São Simão	248292	41566	5012	554059	90.63	15.17	1.83	202.23
Gâmbia-Pontes-Alto da Guerra	220104	36847	4443	491158	80.34	13.45	1.62	179.27
Sado	294678	49331	5948	657569	107.56	18.01	2.17	240.01
Marateca	193644	32417	3909	432113	70.68	11.83	1.43	157.72
Total	**7216344**	**1208069**	**145663**	**16103138**	**2633.97**	**440.95**	**53.17**	**5877.65**

Setúbal wastewater treatment plant will start functioning in 2004. This installation will treat wastewater whose loads correspond to 300000 inhabitants' equivalent. So these pressures although high at the moment due to the non existence of suitable treatment should decrease in the next years.

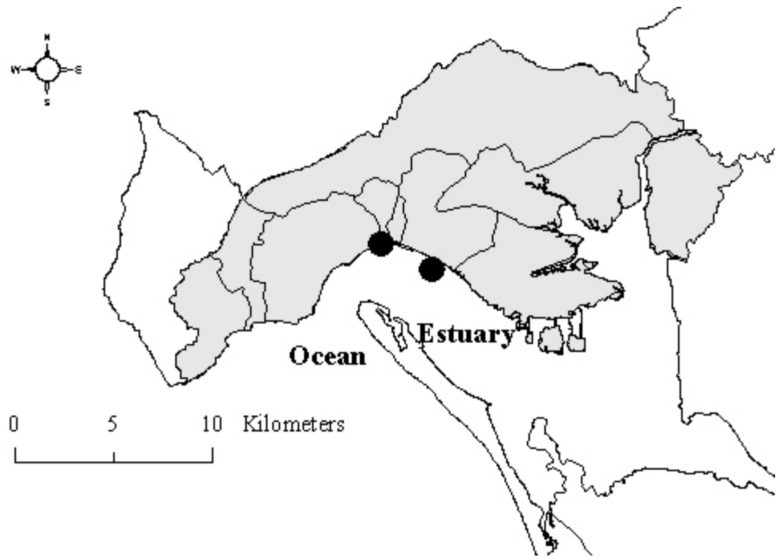

Figure 6: Urban discharge points without suitable treatment.

Non source pollution estimations (Table 11) were collected from Sado's Watershed Management Plan (INAG. 2001). The BOD is low when compared to the urban point sources (about 17 %) but SST corresponds to 47 % of the SST urban wastewater discharges.

Table 11: Annual non source pollution loads.

P ($t.y^{-1}$)	**N ($t.y^{-1}$)**	**BOD ($t.y^{-1}$)**	**TSS ($t.y^{-1}$)**	**Total coliformes (10^6 $NMP.y^{-1}$)**	**Faecal coliformes (10^6 $NMP.y^{-1}$)**
1295.13 (1188192202 inhab-eq.y^{-1})	45010.00 (4978979535 inhab-eq.y^{-1})	453.73 (8402435 inhab-eq.y^{-1})	2771.50 (23000000 inhab-eq.y^{-1})	6.13E+10	1.43E+10

Source: INAG. 2001

CONCLUSION

In this paper it was assessed the **Driving Forces** and **Pressures** categories indicators of the DPSIR framework in a GIS context. This data will be integrated with the other categories of the model for the assessment of the environmental management of the Sado Estuary. GIS is a very useful tool for this kind of data synthesis models since facilitates the visualization of indicators results and also work has a major calculation instrument. Although only some preliminary results of the indicators were calculated and visualized on the GIS, it already allowed discussing the indicator's information and limitations. These results confirm that the Setubal sub-watershed contains clustered populated areas near the city of Setúbal, here are located the major ports and industries, and there are agriculture and aquaculture activities. Due to this high social and economic pressure, a high environmental impact is expected in the north margin of the Sado Estuary.

Further work includes more detail spatial analysis of those categories and the integration in the GIS of all the other categories indicators of the DPSIR, and the different possible links between them. This will allow the assessment of environmental conditions, elaboration of management projects, programs, plans and policies and the design of specific restoration/management actions for Sado Estuary.

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BIBLIOGRAPHY

APSS, 2003 Plano de Dragagens. Porto de Setúbal. Administração do Porto de Setúbal e Sesimbra.

Caeiro. S.. Goovaerts. P.; Painho. M.. Costa. M. H., 2003 Delineation of estuarine management areas using multivariate geostatistics: the case of Sado Estuary. *Journal of Environmental Science and Technology*. 37(18). *4052 – 4059.*

Caeiro, S., Costa, M. H., Paínho, M. and Ramos, T. B. Sado Estuary Environmental Management: A GIS Approach. Proceedings of Euroworkshop ECO-GEOWATER GI and Water Resources Assessment, 9 – 13 Julho, Oxford, Inglaterra. http://www.gisig.it/eco-geowater/VirtualPConference. 1 – 13, 2002.

Cardoso da Silva. M. (1996). Indicadores de Qualidade Ambiental de Zonas Costeiras e Estuários. 3º Congresso da Água. Associação Portuguesa dos Recursos Hídricos. Centro de Congressos da Feira Internacional de Lisboa. Março de 1996.

Casazza. G. Silvestri. C. Spada. E., 2002 Analysis of the marine environment quality using indicators: general overview and examples for the Mediterranean Sea. *Journal of Coastal Research*.

Costanza, R. Towards an Operation Definition of Ecosystems Health. *In:* R. Constanza, B. G. Norton, and B. D. Haskell (ed.). Ecosystem Health. New Goals for Environmental Management. Island Press: 239 – 256, 1992.
Dias. M. D., 1995 Contribution to the Aquaculture Knowledge in the Sado Estuary. IPIMAR (ed.). Setúbal. Portugal.
EEA, 1999a). Environment in the European Union at the turn of the Century. European Environment Agency.
EEA, 1999b) State and Pressures of the Marine and Coastal Mediterranean Environment. Environmental Assessment Series. Nº 5: European Environment Agency.
Elliott. M., 2002. The role of the DPSIR approach and conceptual models in marine environmental management: an example for offshore wind power. *Marine Pollution Bulletin*. 44(6): iii – vii.
Greeuw. S.; Kok. K. And Rothman. D., 2001 Factors Actors Sectors and Indicators (Maastricht University. the Netherlands). International Center for Integrative Studies (ICIS). Working paper I01-E004.
IGEO, 2003. Carta de Ocupação do Solo – COS' 90. http://www.igeo.pt/IGEO/portugues/. Março 2003.
INAG, 2001. Plano de Bacia Hidrográfica do Rio Sado. Direcção Regional de Ambiente do Alentejo. Évora. Portugal.
INE, 2003. Retracto Territorial por NUTS e Concelhos/Distritos e Ilhas. http://www.ine.pt/prodserv/retrato/. Novembro. 2003.
Kelly, K. L., 1998 A Systems Approach to Identifying Decisive Information for Sustainable Information, *European Journal of Operational Research* 109, 452-464.
ME. 2001 Confirmed indicators for the marine environment. Environment performance Indicators (EPI). Ministry for the Environment. New Zeeland. Junho 2001.
Metcalf and Eddy, 1995 Wastewater engineering. MacGraw-Hill. New Delhi, 1334 pp.
Nunneri. C. and Hoffmann. J., Integrated Coastal Zone Management and River Basin Management. Application of GIS for the River Elbe Management (Germany*)*. Proceedings of 5th International Symposium on GIS and Computer Cartography for Coastal Zone Management. 16 – 18 Occtober 2003. Genova. Italy, 2003
OECD, 1993 Draft Synthesis Report, Group on State of the Environment Workshops on Indicators for Use in Environmental Performance Reviews (Organization for Economic Cooperation and Development, Paris).
Picollo. A.; Albertelli. G.; Bava. S. and Cappo. S. The Role of Geographic Information Systems (GIS) and of DPSIR Model in Ligurian Coastal Zone Management. In Proceedings of 5th International Symposium on GIS and Computer Cartography for Coastal Zone Management. 16 – 18 Occtober 2003. Genova. Italy, 2003.
Ramos. T; Caeiro. S. And Melo. J. J., 2004. Environmental Indicator Frameworks to Design and Assess Environmental Monitoring Programs. *IAPA – Impact Assessment and Project Appraisal*. *In Press*.
RIVM, 1995 *A* General Strategy for Integrated Environmental Assessment at the European Environmental Agency. Bilthoven. The Netherlands: National Institute of Public Health and Environmental Protection.
UNEP/RIVM, 1994*An* Overview of Environmental Indicators: State of the art and perspectives. UNEP/EATR.94-01; RIVM/402001001. Nairobi: Environmental Assessment Subprogramme, UNEP.
USEPA, 1999. Environmental Outcome-Based Management: Using Environmental Goals and Measures in the Chesapeake Bay Program (Chesapeake Bay Program. United States Environmental Protection Agency).