IOI - BSOC Leadership Seminar "Using Today's Scientific Knowledge for the Black Sea Area's Development Tomorrow", A.S. Bologa & R.H.Charlier (Eds), Proceedings, 2000, 97-108

INTEGRATED COASTAL ZONE MANAGEMENT AND GIS

R. H. CHARLIER
Free University of Brussels (VUB), Belgium

ABSTRACT

Several disciplines have focused recently part of their attention on the coastal zone. Still the concept of coastal zone remains a rather fluid notion. Perhaps a geographical delimitation might contribute to better define the problems to be handled. Yet the multi- and interdisciplinarity of the studies get diluted in the process. The Geographical Information System (GIS) can significantly contribute to better use of data and insure proper data input, eliminating also overlapping information gathering. It will prove invaluable in mapping and its application covers all domains of geographic, geologic and oceanographic endeavour. Its use can perfect coastal zone study methodology. New technology makes GIS more affordable, yet, its use is, to put it mildly, still quite "timid".

KEY WORDS : coastal zone, GIS, mining, harbours, tourism, mapping

INTRODUCTION

Management of the Coastal Zone, a major concern of decision-makers, land-use planners and environmentalists, has generated an abundant literature while problem solving efforts led to the organizing of numerous training courses, programmes and conferences. Though GIS are approached at the latter, they have not been the core of such meetings.

COASTAL ZONE PROBLEMS AND USERS

Researchers have addressed the topics of users and of conflicts. This author's thoughts have been published in specialised periodicals (e.g. *Journal of Coastal Research, Environmental Conservation, International Journal of Environmental Studies, Geolis, Ocean and Coastal Management*) and conference proceedings, e.g. PIANC-PIC, Coastal Zone Canada, Bordomer, Coastal Zone). Obviously data input from GIS would substantially contribute to refine conclusions and recommendations, hence lead to improved integrated coastal zone management (ICZM). It would concomitantly help, and, enforce coastal zone (CZ) administration.

Coastal protection

Hard structures, from earthen levees to rubble mounds, have been built to protect human establishments against the onslaught of waves and the encroachment of the sea upon the land. The recently developed permeable structure, the HARO® mitigates the effects of the hard structure while nevertheless providing protection. Though negative effects have been established, they remain, in specific instances, a necessary solution where economic dictates are overriding for such reasons as harbour development, transportation, tourism, etc. survival. Evidently decision makers would find GIS data an appreciated tool. "Soft" protection schemes have been developed which work with nature rather than forcefully counteract it; they include beach and berm artificial nourishment, "revetments" and "flow sheets", geotextiles, artificial reefs, vegetation barriers, dune systems, and numerous other approaches (e.g. the "scallop"), some of which are US Army Corps of Engineers classified systems at this time. Their positioning, but also performance monitoring would doubtlessly be enhanced by data provided through GIS.

It is generally believed that a current population migration towards coastal zones - a figure of 50 miles (80 km) is commonly cited - will continue with as much as a 80% concentration predicted for the early 21st century. The ensuing problems better be considered before this population shift overwhelms local, regional, even national planners. Environmental - viz. physical and biological impacts - but also sociological effects are already extensive, users' conflicts have arisen and are due to be further exacerbated, all commonly further challenged by shoreline retreat trends due to natural and anthropic causes.

Though individually addressed, most often site-focused, problems are rarely comprehensively solved and researchers are, if not stymied, then put at a disadvantage by a dearth or even lack of data. The resolution task is quite complex because of the multidisciplinarity and interdisciplinarity of factors and components.

Environmental conservation

After a lull in environmental conservation concern, even a rather strong tide in favour of relaxation or straight elimination of some constraints, a renewed effort at nature protection manifests itself, witness e.g. the policy reversal of Republican Party politicians in the US Senate and House of Representatives. Sustainability and protection of biodiversity are even surfacing concerns. A drastic drop in fish population has been recorded and processing of GIS-provided-data helps in monitoring a situation that causes justified worry.

The supply of phytoplankton, but also the consequences - and uses - of algae has received the attention of EC's DG XII (COST 48 and 49, BRIDGE) and water quality, e.g. cooling and vacuum, of DG XII. European collaborators have participated for many years in these study groups and authored or co-authored chapters in EU sponsored books (*Marine Benthic Vegetation in Europe: European Seaweeds*) (BLUNDEN & GUIRY, 1992; NIENHUIS & SCHRAMM, 1997). The author represented the WGE EFCA at the sendoff meetings of the technical group on cooling intent at producing a rules and recommendations manual, and chaired the Water Subgroup of EFCA, while sitting on Environment Task forces at European and National levels.[1] Most reports have been published under his signature in the scientific literature, and a position paper on "Water Quality and the Consulting Engineer" is to be included in the 2000 Yearbook of the International Water Quality Association (IWAQ).

Users and ICZM

A balanced sharing of the CZ between human occupancy for residential purposes, industrial development and touristic use is challenged by space, but also nuisance, conflicts. For instance this author delivered keynote addresses at, participated in, and co-organized international conferences in Trondheim, Norway (International Geological Map of the World), Bilbao and Santander, Spain (Council of Europe), Surabaya (Indonesia) and Venice (Italy) on land-use conflicts, pollution abatement, coastal protection and bioremediation, and has been called upon as consultant for coastal mining projects for impact (both EIA and SIA) (Australia), harbour rehabilitation (Baltic States), navigation channels development (Vietnam, Albania, Argentina *et al.*), for works and monitoring along the Belgian coast. Remote sensing and GIS have thus routinely been used in connection with such travails, and in recreational and touristic matters (e.g. personally in Belgium and Morocco), touching upon land-use, siting coastal defences, water quality, sociological and cultural impact. Much has been said about coast access. A lesser

[1] Acronyms: WGE EFCA: Working Group Environment of the European Federation of Consulting Engineers Associations: PIANC-PIC: Permanent International Association of Navigation Congresses - Permanent International Committee

problem in Europe than in the US because of another approach to the eminent domain doctrine, it remains gainsaid that GIS information on public access, even to private property, would enhance tourism planning. In many projects the plight of industrial fisheries and mariculture has been opposed to the constraints of shipping and harbours activities. Collaborators have looked into neighbourhoods of harbours, coastal industries and seaside tourism (Romania, Bulgaria, Lebanon). Though mangrove environments are a lesser concern for Europe, they and forestry and agricultural lands would gain, in planning from increased input from GIS. Information would, naturally, be highly valuable for marine research, and for surveys and policy formulating in the area of human health.

One quality required of all GIS is to be jargon-free and user-friendly. ICZM indeed is an endeavour that involves generalists who are not necessarily "informatics" specialists.

GIS has been widely involved in North Sea Coastal Zone management planning ranging from inland waters bio-remediation (cf. *Sea Technology* papers), to beach and berm nourishment (cf. *Journal of Coastal Research* papers), to artificial islands.

In securing data for its tasks, industry has utilized remote sensing, existing and self-created maps, conducted surveys and examined archival materials. It has analysed geographical and geological sources. Gathered information has been mapped and statistically analyzed, and time series used. Every effort was made to format information so that it could be used for a four-dimensional approach to the problem at hand. Interpolation was effectuated, and in some cases extrapolation made so as to provide ICZM for the relatively near future (Fig.1).

SYSTEM

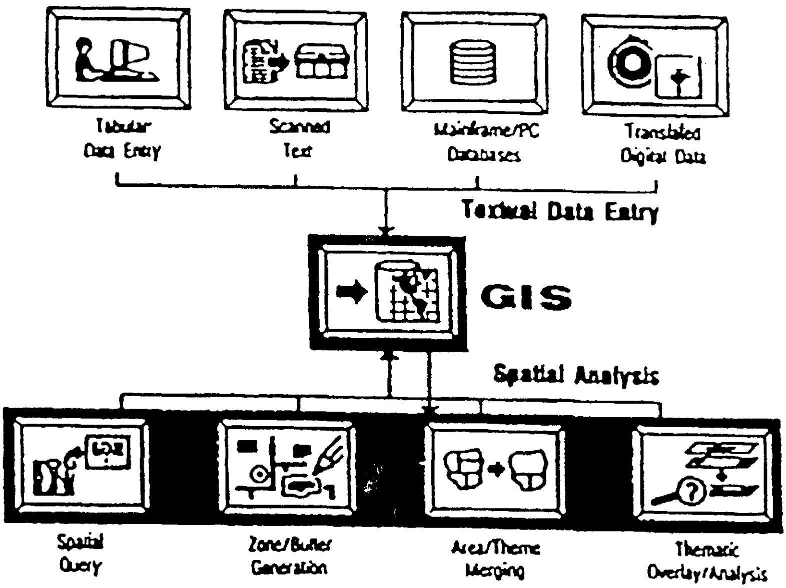

Fig.1 - Flowchart of GIS

Evidently, reports include maps, graphs, charts, diagrams, tables, visual materials (with sometimes overlaps). While each text is prepared in easily interpretable language, occasionally animated and/or stationary displays have been constructed.

MANAGEMENT OF SYSTEM

Some users may not wish to examine every image/document available and prefer to combine information provided by conventional and satellite furnished data. And/or they should also be able to insert and integrate own observations/data in the "programme" provided. The questions to be addressed include:

- number of data levels that can be manipulated
- possible operations
- preferred format
- system's transparency quality for datatype
- data storing method
- accession to other system(s) method

RECENT DEVELOPMENTS IN GIS USE AND APPLICATIONS

Though the need has been recognized for some time, GIS have not been extensively applied to integrated coastal management, hence to "water-related" matters. Yet, for instance, wetlands' health can be assessed by a computerized GIS that would integrate satellite-gathered land-cover data. It would permit decisions-makers, viz. coastal zone managers, to view an entire ecosystem rather than segments. Apparently bad experiences in the eighties have generated reluctance on the part of users, particularly local administrators, to rely on GIS. Though taxation and administrative applications use are common, natural resources ones are still rather rare.

It is gainsaid that a GIS approach could foster an intensive collaboration between scientists, engineers, policy experts and coastal zone managers. And, clearly GIS are an educational tool with a serious potential to enhance better land-use decision taking at the local level. Indeed, local governments maintain a variety of records at spatial scales, which data is useful to coastal zone planning and management. The recent growth by local governments warrants thus apparently the exploration of GIS use. Teaching models are used as feedback systems for monitoring a wide range of phenomena, both natural and social, not omitting economic ones.

Based on the perusal of recently published bibliographies of current GIS use (1990, 1995), it is apparent that its applications involve overwhelmingly, on the one hand, national governments agencies, and, on the other, much of academe (c.f. CANESSA, 1999).

It has been proposed to create a GIS for ocean planning along the coasts of the southeastern United States. Notwithstanding the fractionalisation of jurisdictions in the United States, comprehensive planning governance will thus be enhanced as GIS can help in decision making, identify conflict areas and bring together wider community participation. According to some authors this is a new application of GIS, used primarily for land-based applications, ocean data being more sparse. We may tend to differ with this view though ocean focused GIS are less frequent than terrestrial ones. True, the dynamic nature of a shoreline, caused by erosional processes and tidal phenomena, is difficult to capture in a GIS. Shoreline definition, bathymetry and boundaries delineation are among the fields to be covered. NOAA sees building an ocean planning GIS as an excellent opportunity "to build partnerships between the federal and State sectors in support of ocean resource management. In addition, this project aids in levering and coordinating institutional resources and applying them to specific coastal issues, such as habitat protection; and coastal hazards, as well as ocean planning and governance". Photography, and photogrammetry, has been, of course, associated with GIS.

SITING A TREATMENT FACILITY IN A COASTAL ZONE SETTING

Treatment facilities are undesirable neighbors, hence their localization involves geological, hydrological, climatological, pedological, seismical, engineering, ecological and social-economic considerations. As a central facility in small or medium-sized countries is definitely far less onerous than several small plants, the site choice is the more crucial. A digital data base management system is well suited to handle the numerous informations which will bear on the decision (GIS). The approach has been applied in Cyprus for industrial waste disposal (FATTA *et al.*, 1998).

The following steps were taken: specification of the **location constraint criteria**, collection of information in digital format with transfer of point, line and area data from original documents to a base map and placement of data in a polygon data structure (or conversion of polygon-to-raster), manipulate date. By buffering (proximity analysis) and overlay procedures maps conforming to specific criteria were created.

The actual site selection process was a step by step approach evaluating alternative and gradually narrowing the geographical focus. The GIS proved thus a powerful tool for environmental problems of interrelated systems analysis. The GIS is, however, not free of some disadvantages as overlays are difficult to comprehend when many factors are involved, do not allow taking into account that underlying factors may be of unequal importance, and the outcome is very sensitive to threshold levels used in the analysis (CARVER, 1991).

Among present users are, of course, map makers, who wish to pinpoint areas most suitable for what is perhaps euphemistically labelled "development", managers of water resources protection (fostering increasing interaction between web and GIS), parties responsible for coastal hazards mapping (digital base maps), and those in charge of assessments (viz. zoning, land-use planning, allocation of resources for property damage mitigation plans, water resources management). Models have been developed in which multiple organizations participate in the development of GIS applications and data base. GIS can be used as an aid to decision making, as hinted at higher, identify conflict areas, and bring together a broad user community interested in similar problems (Table 1).

It is evident , and apparent, that GIS addresses itself to the Internet community, the geospatial user community, environment managers, researchers in various domains, and coastal and marine resources managers. The Internet itself holds a great potential to overcome the limitations of fixed media, with watershed management as a prime example. Such management can be improved now thanks to technological advances and the cost lessening of computers and software which make GIS affordable.

MEDIO wrote in his paper on the "General background to the assessment and management of diving-related tourism on a Red Sea marine protected area", at BORDOMER 1995: " Public awareness and education efforts in marine protected areas throughout the world are, in most cases, at an embryonic stage", yet "tourism damage can be reduced through the use of an adequate education campaign." He was, and is, by no means alone, nor is his geographic area unique. The same warning bell is sounded by reports from among other countries Kenya, Nigeria, Taiwan.

GIS techniques have ben used in the development of sensitivity maps and databases as presented at BORDOMER 95 by J. MICHEL, J.A. DAHLIN and M.O. HAYES. In Vietnam and Nigeria they were put to work to study coastal change and in environmental management, while in Arcachon Bay (France) they were found valuable for administrative management and environmental follow-up. Their utilization is expanding e.g. in the analysis of soil erosion in France's Gironde and Adour estuaries, the antipollution efforts in Douarnenez Bay (Brittany), environmental conservation in coastal lagoons (Brazil), oyster culture management, and ICZM in Nigeria. Wetlands and environmental applications warranted a 1995 400 pages book by J.G. LYON and J.McCARTHY (CRC Press-Springer)!

GIS has been used in marine conservation and integrated coastal management (BECKMAN, 1998; VALLEGA, 1998).

In some areas it was thus possible to prepare plans on how to achieve sustainable development, to guide future uses along the shoreline, to prioritize water-dependent and water-related activities in marine use areas. The GIS provided an inventory of

Table 1

GIS potential use examples in ICZM

Coastal protection	Shoreline retreat/modification Longshore current direction Sedimentation patterns Nourishment depletion Beach width/length
Fisheries	Catch Species diversity
Aqua/mariculture	Yield Species
Tourism	Users numbers Types of tourism Users economic/occupation types Season's duration Accomodation types
Mining	Products exploited Commercial importance Areas covered
Dredging, Harbours operations, etc...	

countywide saltwater accessible parcels, and a marine use regulatory study was completed. This GIS inventory focused on land side and water side attributes of each parcel involved. The analysis gave planners and resource managers a mechanism to balance growth and new development for facilities while protecting coastal resources and minimizing environmental impacts on sensitive marine habitats.

In Florida, MRGIS' (Marine Resources GIS), developed since 1983, database "exploded" in the nineties. MRGIS has become a *de facto* clearinghouse for coastal and geospatial data sets. Among the active programmes are the Florida Keys national marine sanctuary, which includes a water quality protection side, the Statewide ocean resources inventory, "surf your watershed", Florida marine web forum, and the Federal Geospatial Data Committee National Geospatial data clearinghouse proposal.

Other States have GIS schemes that accommodate hundreds of information requests each year, Wisconsin being an example. California has numerous GIS but they do not cover the entire natural system that needs to be managed; officials complain that there is a lack of consistent data access standards, data format and metadata structure. Massachusetts has begun a mapping of its coast using GIS and aerial photography. NOAA is designing and creating an "ocean GIS" which will prove an asset a.o. in eutrophication monitoring: it intends to unify and avoid contentious matters while providing a solid platform for planning. In a concerted effort to look at water-related problems, particularly quality, NOAA has developed an *environmental sensitivity index*, and established, with GIS/Remote Sensing help, a marine spills digital map.

Environmental Sensitivity Index (ESI) maps are an integral component of oil-spill contingency planning and response, environmental assessments and regulatory decision-making, and atlases have been generated using GIS approach. Thus are provided shoreline classification, biological resources surveys and human-use resources data. Natural resources are mapped using general guidelines for each element and species groupings within each such element. Human uses encompass, evidently, recreational locations, managed areas, resources extraction sites and cultural resources.

In Rhode Island, a RI DEM GIS (Rhode Island Demonstration Geographical Information System) coordinator digitizes information on base maps and incorporates them into RI GIS to develop coverages and GIS-generated resource maps. North Carolina's "ocean plan" includes an "ocean resources data in geographic information system format". In California, the MC Corporation of Redlands has built a geo-bibliography into the GIS; siting of coastal development projects may henceforth be made in the light of GIS views that can be rapidly displayed and circulated. "An important side benefit is that the terms of reference for future contracts for work in the coastal zone will make available to bidders the information already residing in the GIS." In the State the ability to use GIS is, however, hampered by institutional and technical problems.

In Wisconsin a coastal GIS project, launched in 1995, led to a strong interest in GIS training; development however was harmstrung by dearth of funds. The University of Delaware called upon a GIS to develop strategies for the improvement of the coastal ecosystem's health. The University of Connecticut is involved in educational projects aimed at bridging the gap, at local level; between natural resource protection and GIS technology, GIS and Remote Sensing are, for instance, used to show the connections between land-use and water quality.

GIS technology has been applied to beach erosion in the Gulf of Guinea. It may prove of appreciable value to correct worrisome situations such as salt water intrusion, disruption of coastal communities, threats to waterfront touristic complexes, economic and social impacts.

On France's Côte d'Azur a study has been conducted to handle the sea-land interface on an area 200 m wide, 100 m on each side of the 0 level. It allowed to graph the characteristics of the coast line for the entire geographical ensemble, some 55 km, and detail by "slices" of 5 km using geographical symbols, to draw a transversal profile according to the selected line number, to calculate the value of the true, or pseudo-true global linear element, and more, thus allowing local decision takers to rapidly create descriptive file cards for each coastal linear element for which he/she bears responsibility. The technique was applied to the western portion of the Bay of Cannes.

CONCLUSION

Obviously a concerted effort at GIS use in connection with integrated coastal zone management is timely and it may be disclosed that the European Union Commission is actively examining such move.

An ocean GIS can serve as an unifying and non-contentious platform for regional ocean planning and policy dialogue. Ocean resources data maps in GIS format can help significantly in establishing unequivocal jurisdictional boundaries, bathymetric measurements, outlining outer continental shelf lease blocks, siting major shipwrecks, artificial reefs, hard bottom zones, seabirds concentrations, turtles nests, disposal areas, and potential sites for non-living resources. GIS systems will prove useful in drawing attention upon shoreline geomorphological features, current beach access, and man-made structures such as piers, groins, jetties, revetments, seawalls and stormwater outfalls. Specific coastal issues, e.g. habitat protection and coastal hazards, can thus better be addressed.

A subregional GIS provides beach erosion and coastal flooding information and siting of coastal development projects may profit from readily consultable GIS data. Main areas of concern to this approach have been listed as capacity building to support the GIS, collection and distributions centres of marine and coastal information at approved national institutions, continued co-operation amongst governmental units for support and maintenance of the GIS itself. Decision makers and GIS information could "interface" so that environmental, social and economic values be inserted in the decision process, the public-at-large, stakeholders, resource-managers and officials interact, alternative scenarios' (to a proposed one) possible outcomes be visualized and measured, different values conflicts areas be identified.

A computerized GIS integrating satellite gathered data can assess wetlands conditions. Such technology provides also tools to tackle oil spill contingency planning and response, as well as environmental assessments. BARTLETT (1990) has noted that despite lack of apparent progress in developing operational GIS for the coast, the need for automated data handling [...] has long been recognized. Still according to MILLER *et al.* (1997) and ARNOLD *et al.* (1997), application of GIS to coastal management is far from widespread. Yet, an ocean planning GIS, for instance, provides an excellent opportunity to foster partnerships for ocean resource management between national and regional, even local, agencies.

Each aspect of geography may cooperate with other disciplines to forge an effective approach to find solutions to the problems, and the dangers, facing the coastal zone. To mind come: population shifts, use conflicts, pollution abatement, multiversity, economic realities, coastal protection against erosion, management with a view on sustainability.

At the dawn of the 21st century, it is not too early to reduce the talking and the publication of lofty exhortations, and to glide from the planning to the doing. Most scientific disciplines have an input.

The coastal zone study methodology can certainly be perfectioned and updated by use of GIS (CHARLIER, 2000; CHARLIER & CHARLIER, 2000)..

The GIS places at decision-makers' disposal a powerful tool for analysis of spatial information; it allows data manipulation when needed (VAN TWEMBEKE,1996). FATTA *et al.* (1999) stressing the special environment type of small islands which are faced with rather limited development options used the system for problems facing Cyprus. The digital data base management system accepts multi-source large volumes of spatially distributed data, stores, retrieves, analyses and displays user specified accumulated data (CARVER, 1991; LAKSHMAN, 1991: STAR & ESTES, 1990).

REFERENCES :

ARNOLD C.L., STOCKER J.W., PRISLOE M.P., 1997 - Better Land Use Decision at the Local Level, *Coastal Zone 97*, Boston MA Abstr.: 723-725.

BARTLETT D., 1990 - *Spatial Data Structures and Coastal Information Systems, Egis '90,* Egis Foundation, Amsterdam, The Netherlands: 30 pp.

BARTLETT D., 1993 - *GIS and the Coastal Zone: An Annotated Bibliography.* National Centre for Geographic Information and Analysis, Santa Barbara CA (NCGIA Rep. 93-9).

BECKMAN L., 1998 - Marine Conservation in Canada: a non-governmental perspective on what marine policy should work like, *Ocean Yearbook XIII*: 211-244.

BLUNDEN P., GUIRY J. (Eds.), 1992 - *European Seaweeds,* J.Wiley & Sons, Chichester.

CANESSA R.R., 1999 - *Geographical Information Systems and the Coastal Zone Conflicts*, Univ. of British Columbia, Vancouver BC.

CARVER S.J., 1991 - Integrating multi-criteria evaluation with Geographic Information Systems, *Int.J.Geogr.Info.Syst.*, **5**, 3: 321-339.

CHARLIER R.H., 2000 - The Shrinking Playground, *IOI-BSOC Leadership Seminar "Using Today's Scientific Knowledge for the Black Sea Area's Development Tomorrow"*, A.S.BOLOGA & R.H.CHARLIER (Eds), Proceedings: 133-145.

CHARLIER R.H., CHARLIER C.C.P., 2000 - Sustainable Multiple-Use and Management of the Coastal Zone, *IOI-BSOC Leadership Seminar "Using Today's Scientific Knowledge for the Black Sea Area's Development Tomorrow"*, A.S.BOLOGA & R.H.CHARLIER (Eds), Proceedings: 109-131.

FATTA D., SARAVANOS P., LOIZIDOU M., 1999 - Industrial waste facility site selection using Geographical Information System techniques, *Int.J.Env. St.*, **56**, 1: 1-14.

LAKSHMAN S.Y., 1991 - Is GIS appropriate technology ? *Int.J.Geogr.Info.Syst.*, **5**, 1: 41-58.

MILLER A.H., NIEMANN B.J., VENTURA S.J., 1997 - Coastal Management and GIS, *Coastal Zone 97*, Boston MA Abstr.: 718-722.

NIENHUIS P., SCHRAMM W. (Eds.), 1997 - *Marine Benthic Vegetation in Europe*, Springer Verlag, New York-Heidelberg.

RICKMAN T.L., MILLER A.H., 1995 - *A Categorized Bibliography of Coastal Applications of Geographic Information Systems,* Univ. of Wisconsin Sea-Grant Inst. & Land.Inform. and Computer Graphics Facility, Madison WI.

STAR J., ESTES J., 1990 - *Geographic Information Systems. An Introduction.* Englewood NJ, Prentice-Hall.

VALLEGA A., 1998 - Integrated Area Management in the Framework of the UNEP Regional Seas Program: The Lesson from the Mediterranean, *Ocean Yearbook XIII:* 245-279.

VAN TWEMBEKE U., 1996 - Het Geografisch Informatiesysteem (GIS) als beleidsinstrument en basis van de besluitvorming, *Bull.Séances Acad.Roy.Sci.Outre-Mer,* Belgium, **42**, 3: 626, 631-643.