Coastin

A Coastal Policy Research Newsletter

Number 1

September 1999

Contents....

Editorial

Welcome to the first issue of COASTIN, a Coastal Policy Research Newsletter. With this issue, TERI launches a new dimension to its research agenda – that of work on coastal policy. As India and other developing countries reach higher levels of economic growth, there is bound to be pressure on the coast arising from external drivers such as new investments, and internal drivers of increased population, rural–urban migration and a growing middle class with rising needs and aspirations, and the inherent attraction of the coast as sites for industry, tourism, and settlements. These drivers will have impacts on the coastal environment which, if unguided, may result in severe stress in these regions. Therefore, there is need for evolving clear policies to guide coastal development activity and environmental protection, based on a review of existing policies and on new research.

The INCO-DC project, 'Measuring, Monitoring, and Managing Sustainability: The Coastal Dimension' seeks to do just this. It seeks to understand current coastal developments in India and to suggest a more sustainable path for future developments. This project aims, through a study of selected locations, at identifying the key variables affecting coastal resources and ecosystems, the policy choices faced by decision makers, and the information requirements and decision-making instruments necessary for effective management. This biannual newsletter is part of its ongoing dissemination activities. The project involves seven partners, three Indian and four European. The newsletter is a combined effort of all partners, but it hopes to extend outward and attract contributions from researchers, policy-makers, and non-governmental organizations in the field. This issue introduces the project and reports on the Expert Meeting on 'Coastal Hot Spots' held on 22 February 1999 in Goa, India. Future issues of this newsletter will carry updates relating to the project from the seven partners, a paper relevant to issues of sustainable coastal development, summaries of recent literature on project related subjects, and forthcoming events and meetings relating to coastal issues.

We invite you to be part of this new policy discourse.

R K Pachauri, Director, TERI

teri

European Commission

Measuring, monitoring, and managing sustainability: the coastal dimension

List of partners

COORDINATOR
TERI
Western Regional Centre
Models Residency, B-7, G-6
Near St. Inez Church
Panaji – 403 001, India
Tel. 91 832 425 290/421 264
Fax 91 832 232 530
E-mail terigoa@goa1.dot.net.in
*Dr Maria Ligia Noronha**

PARTNERS
Universidade Nova De Lisboa
Socinova
Gabinete De Investigacao Sociol. Apl.
Avenida De Berna 26-C
1050 Lisboa, Portugal
Tel. 351 1 793 35 19
Fax 351 1 797 77 59
E-mail nelson@mail.eunet.pt
*Prof. Nelson Lourenco**

Laboratorio Nacional De Engenharia Civil (LNEC)
Depto. De Hidraulica
Avenida Do Brasil 101
1799 Lisboa Codex, Portugal
Tel. 351 1 848 21 31
Fax 351 1 847 38 45
E-mail lferreira@lnec.pt
*Dr João Paulo Lobo-Ferreira**

Instituto Cartografic De Catalunya
Parc de Montjuic
08038 Barcelona, Spain
Tel. 34 3 425 29 00
Fax 34 3 426 74 42
E-mail jmarturia@icc.es
*Dr Jordi Marturia**

Universita Degli Studi Di Trieste
Depto. Di Biologia
Via Giorgieri 10
34100 Trieste, Italy
Tel. 39 40 676 38 79
Fax 39 40 568 855
E-mail feoli@univ.trieste.it
*Prof. Enrico Feoli**

National Institute of Oceanography
PO NIO
Dona Paula – 403 004, India
Tel. 91 832 221 322
Fax 91 832 223 340
E-mail kalidas@csnio.ren.nic.in
*Dr Kalidas Sawkar**

Goa University
Dept of Geology
SPO Goa University
Taleigao Plateau – 403 205, India
Tel. 91 832 22 13 48
Fax 91 832 22 41 84
E-mail chachadi@unigoa.ernet.in
*Dr A G Chachadi**

* Contact person

The project 'Measuring, monitoring, and managing sustainability: the coastal dimension'[1] is supported by the European Commission – DG XII under RTD (Research and Technological Development) activities. Adopting a multi-disciplinary approach, the project involves investigations on how societal driving forces – demographic, commercial and market, cultural, and technological – interact with natural systems and impact on coastal resources of India. From these investigations it proposes to design a system to measure, monitor, and manage coastal area development with a view to promote sustainable economic development. More specifically, the project aims at studying selected locations to identify (1) the key variables affecting coastal resources and ecosystems, (2) the policy choices faced by decision makers, and (3) the information requirements and decision-making instruments necessary for effective management. The project has seven partners: three Indian and four European, and is coordinated by TERI.

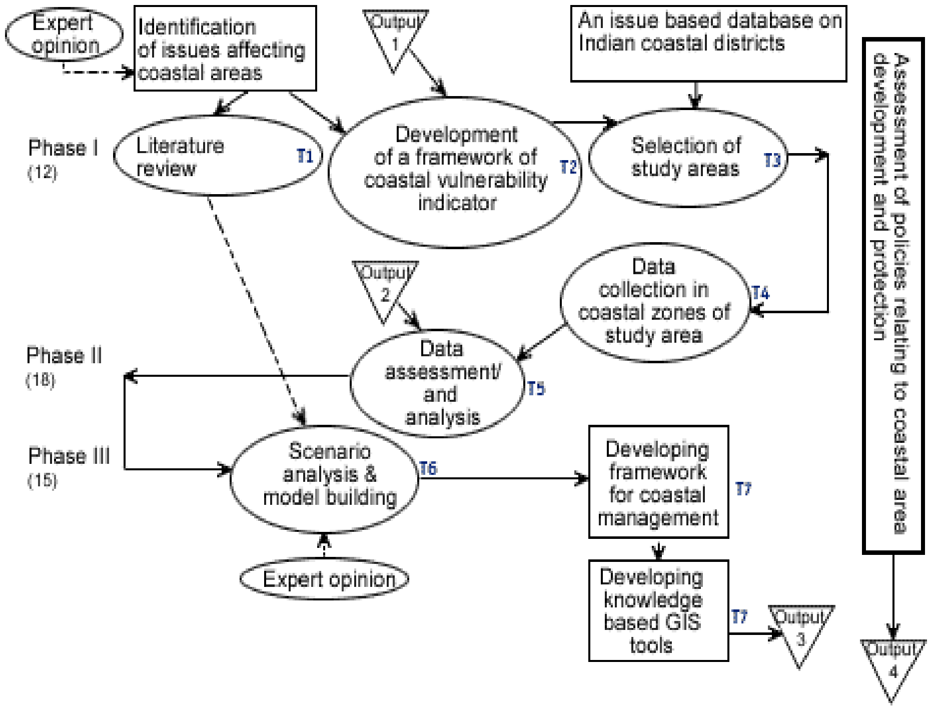

FIGURE 1 Research plan

Activities

The key activities involve the following.

- A survey of the available policy and scientific literature on the state of development and the environment of coastal India. This, along with expert opinion, will enable the development of a framework of indicators of 'coastal vulnerability'.
- These coastal vulnerability indicators will be used to select some coastal districts of India as being more vulnerable to development and/or currently 'hot spot districts'.

[1] Project code no: ERB3514PL97335

- Within these coastal districts, an ecosystem-cum-administrative approach will be used to actually select the areas which will be investigated intensively to study the interrelationships between development and the environment. At these locations, data on vegetation, groundwater, coastal land and water quality, and socio-economic parameters will be collected and analysed to assess the future options for development.
- A modelling framework will be developed to integrate the submodules that correspond to the studies above. A GIS (Geographical Information System) based decision tool will be developed on the basis of this framework to measure, monitor, and manage sustainable use of coastal resources.

The project expects to develop a commentary on policies, both regulatory and other, that guides coastal development activity and environmental protection.

Meeting of experts

Under the project 'Measuring, monitoring, and managing sustainability: the coastal dimension', a meeting of experts on coastal development issues in India and the South Asian region was held on 22 February 1999 in Goa, India. The 33 participants (*see list p. 11 to 12*) included scientists and policy makers from India, Sri Lanka, Bangladesh, and the Maldives, and the partners to the project.

The meeting had a technical session with four presentations and two panel discussions on 'coastal hot spots'. In the technical session, Mr Rakesh Mehta, Development Commissioner of Goa, highlighted the demands on India's coasts and the conflicts and opportunities that these present (*see p. 3*); Dr Elrich de Sa, Director, the National Institute of Oceanography, Goa spoke about the state of the coastal environment in India (*see p. 5*); Prof. Nelson Lourenco of the Universidade Nova de Lisboa, Portugal discussed the integration of socio-economic data sets in land use change studies (*see p. 7*); and Dr Lobo-Ferreira of the Laboratorio Nacional De Engenharia Civil, Portugal presented the European Union experience on groundwater vulnerability assessments and mapping (*see p. 8*).

Demands on the Indian coasts

opportunities and conflicts*

R Mehta
Development Commissioner, Goa, Government of India

A country of subcontinental proportions, India has a 5700-km-long coastline and an EEZ (exclusive economic zone), covering 2 million km^2; nine states and three union territories share the resources of the coast. The life of its people, unbroken by the political upheavals of the past, is now changing fast due to the impact of growing global trade and integration with the world economy. Hence, the earlier faith that the society had in its inherent strength to adapt to a way of life which was sustainable for the environment is fast eroding. The coastal belt is perhaps the most threatened by the rapid changes taking place in the country.

The central concern of planners since the World Environment Summit in Rio de Janeiro in 1992 has been achieving sustainability, i.e., how to balance nature with development to ensure greater economic opportunities. Since two-thirds of the world population lives within 50 km of salt water, the pressure on coastal and island systems is increasing. These demands arise out of the increasing urbanization and industrialization – an upshot of the developing countries' race to catch up with the developed world. The development of infrastructure for ports, tourism, and recreation centres has resulted in a consequent growth of pollution, destruction of wetlands, lagoons, mangroves, estuaries, beaches, and erosion of the coastline. Any approach towards understanding and tackling these problems has to do with people's lives and livelihood.

Since human activity encompasses the coast and the hinterland, the impact of coastal activity can be felt at considerable distance in time and space. For example, export of wood from the port has an impact on deforestation; discharging pollutants into the sea has an

---

*This is an abridged version of the paper presented by Mr R Metha at the Meeting of Experts on 22 February 1999. The unabridged version is available on www.teriin.org impact on fish resources, and even impacts the movement of sea currents, which in turn affects the air currents and rain-bearing clouds and temperatures. The interdependence of the various factors is apparent but greater study is needed to establish the linkages.

The demands on the coast are governed by a conflict of interests, which are both within groups and between them. For example conflicts occur between the following uses and users.

- Mangroves are destroyed for fuelwood, settlements, and fishing, but their existence is essential for preserving the coastline.
- Small, medium, and large fisherman have conflicts over the areas in which fishing can be done and the quantity which should be allowed.
- The exploitation of the various resources of the sea, namely gas, oil, minerals, and prawns causes conflict over space. The belief in unexplored resources of the coastal seabed has added a new dimension in defining the EEZ through the law of the sea.
- The possibility of future potential which may be discovered has escalated territorial conflicts in many countries, e.g., Spratly Islands, yet unexplored Arctic and Antarctic Circles.
- 'Traditional' culture conflicts with the 'development' culture among people residing in coastal areas, e.g., the North–South highway in the Andaman and Nicobar Islands that was meant to bring the fruits of development to the local population became a source of conflict between them and the migratory settlers who were viewed as encroaching on their habitat.
- The diversity of the coastal environment conflicts with attempts at imposing a single 'model' of growth as seen in the exploitation of the commercial potential of the coastal areas.
- Needs of a consumerist society for new goods and services conflict with the increasing inability to accept the pollutants caused by the very system of production which meets these needs.

These conflicts of interest raise a number of issues for coastal management including the need for management comprehensiveness and, transparent and data-based policies. It also points to the need for conflict resolution mechanisms to ensure that 'might' is not always 'right'. The recognition of diversity of the coastal environment would preclude a single 'model' management plan to fit all types of cases. It is important to ensure the participation of local communities in any management plan to avoid their marginalization.

Opportunities

While there are challenges, there are opportunities as well. The history and culture of India as an unbroken civilization has a lot of lessons for us. There are communities living in India in harmony with the environment because they have evolved an elaborate system of enculturation of environmental values over hundreds of years. For example, the Bishnois of Rajasthan have learnt to live in perfect harmony with the wild beasts and suffer no economic deprivation on that account. We should learn from the mistakes of the world and not repeat them. The great challenge is how to involve people in the process of sustainable growth. This calls for a complete overhaul of the policy formulation methodology. We should try to have a bottom-up approach to planning instead of the top-down approach followed hitherto. This would ensure that the diversity of the environment is recognized and included in the planning process.

In conclusion, there is an urgent need to address the challenges to the coastal environment in India. Since there is interdependence between the coast and the hinterland, the dynamic relationship needs to be studied while looking at a resolution of the conflicts and the answers to the sustainability question. In developing countries such as India the race to 'catch up' the missed years of growth may lead to less importance being given to issues of sustainability. The choice for them is whether to follow a known model or discover a new one. Developing countries need to ponder on the question of balance and find the solutions.

Your comments and contributions to this Newsletter are most welcome.
The next issue is due in March 2000. Please direct your mail to

Ms S Sonak
TERI
Models Residency Unit, Block 7, G 6
Near St. Inez Church, Panaji, Goa – 403 001
Telephone 91 832 42 5290
E-mail terigoa@goa1.dot.net.in

Present state of the coastal environment in India*

Elrich de Sa
Director, National Institute of Oceanography, Goa

The US Commission on Marine Science, Engineering, and Resources defines the coastal zone as 'that part of the land affected by its proximity to the sea, and that part of the ocean affected by its proximity to the land'. Box 1 gives some interesting facts about the coastal domain and the coastal ocean.

Pollution in India

Most coastal pollution in India arises from land-based sources – industrial and domestic wastes and agricultural run-off. Shipping and associated ship-building, breaking, and port activities are becoming increasingly significant. Coastally located industries that have cropped up recently use seawater as a resource and the coastal domain as a sink of altered seawater. These pose newer, more direct threats to sensitive ecological areas. The type and quantum of pollutants released into the coastal ecosystem of India are given in Table 1.

Translating the table of cumulative discharges in the coastal seas to hot spot locales, we have, in Gujarat, industries discharging over 200 MLD of effluents which are acidic, oxygen depleted, and sediment laden. The river Kalu, north of Mumbai, flowing through the industrial towns of Ambarnath, Ulhasnagar, and Kalyan has a mercury concentration exceeding 100 ppm. In Calcutta, the Hoogly river waters are contaminated by *E. coli*, shigella, salmonella, and other human pathogens – indication of severe sewage contamination. In Goa, estuarine and coastal waters are 'clean', though there is high sediment load from mining activities. The Mandovi-Zuari estuaries receive over 30 MLD of partly treated domestic sewage and 15 MLD of industrial and agricultural effluents.

However, the data, to date, indicate that the Indian coasts have well-circulated oxygenated waters and that hot spots remain contained within reasonable limits.

Box 1 Costal domain and ocean: some facts

- The coastal domain from 200 m above to 200 m below sea level
  - occupies 18% of the surface of the globe
  - is the area where around a quarter of global primary productivity occurs
  - is where around 60% of the human population lives
  - is where two-thirds of the world cities with population of over 1.6 million people are located
  - supplies approximately 90% of world fish catch
- The coastal ocean accounts for
  - 8% of the ocean surface
  - <0.5% of the ocean volume
  - around 14% of global ocean production
  - up to 50% of global oceanic denitrification
  - 80% of the global organic matter burial
  - 90% of the global sedimentary mineralization
  - 75%–90% of the global sink of suspended river load and its associated elements/pollutants
  - more than 50% of present day global carbonate deposition

Table 1 Type and quantum of pollutants in the Indian coastal ecosystem

Input/pollutant	Quantum (annual)
Sediments	1600 million tonnes
Industrial effluents	50×10^6 m^3
Sewage (largely untreated)	0.41×10^9 m^3
Garbage and other solids	34×10^6 tonnes
Fertilizer (residue)	5×10^6
Synthetic detergents (residue)	130 000 tonnes
Pesticides (residue)	65 000 tonnes
Petroleum hydrocarbons (tar ball residue)	3500 tonnes
Mining rejects, dredged spoils, and sand extractions	0.2×10^6 tonnes

Physical processes operating along Indian coasts

Only in the last decade has there been a general understanding of the large-scale dynamics of the coastal circulation in the Arabian Sea and the Bay of Bengal. A complete understanding of the dynamics of the estuaries is still awaited, but general features and the influence of remote forcing are acknowledged.

Large-scale currents along the outer shelf and beyond, around India, reverse seasonally with the monsoon winds. The currents form a continuum from the northern Bay of Bengal to the northern Arabian Sea. It is expected that large-scale currents, tides, winds,

*This is an abridged version of the paper presented by Dr Elrich de Sa at the Meeting of Experts held on 22 February 1999. The unabridged version is available at www.teriin.org and river run-off influence currents on the inner shelf. Tides, winds in season (and sea-breezes), and river run-off would be the major influences nearest the coast. The beneficial effect that the tidal currents have on the coasts of India is clear. However, the along shore component that can carry pollutants coastally may never be significantly strong enough to counter the dilution effects during transport.

This seems to be consistent with the COMAPS (Coastal Ocean Monitoring and Prediction System) data sets which indicate that India's coastal waters are clean and well oxygenated with no detectable spread of hot spot influence. The large rivers on the east coast also play a role in confining along shore pollutant transport, with their large run-offs acting as barriers to close-to-coast transport of pollutants and sediments.

Sensitive environments

Indian coasts have a large variety of sensitive ecosystems including sand dunes, coral reefs, mangroves, seagrass beds, and wetlands. Some of these are the spawning grounds and nurseries of a number of commercially important fishes, gastropods, and crustaceans. A critical feature of these ecosystems is the variety of bioactive molecules that they host. Recent mining of organisms from the tidal and inter-tidal zone has revealed large numbers of molecules with obvious application for human health and industrial activity. This could be the most commercially important aspect of the coastal zone. Molecules that show bioactivity from one ecosystem may not show the same activity, or level of activity, when mined from a different locale or different season. This feature alone should be reason enough for the protection of *all* such ecosystems, and not only representative isolated units in protected areas/parks.

Measurement and monitoring

A systematic long-term study of pollutants in a regional context and their effects on biota is necessary. Levels and distribution of contaminants need to be measured and monitored over long periods of time, in the water column, the sediment, and the biota. Continuous information on the sources of pollution, the routes of distribution in the environment, and their progress through ecosystems is required. Similarly studies on bio-concentration, bio-accumulation, and bio-magnification of pollutants are needed.

The scheme for what parameters should be measured where, when, and how often, is complex. It requires careful planning to maximize the data collected per unit of cost and effort. Monitoring schemes in sentinel organisms or choice of bio-makers, have to be carefully considered to ensure the natural availability of the same species along the Indian coasts. Choice of different species for different areas has to be carefully evaluated in the lab and *in-situ*.

Synoptic monitoring tools of moored buoys and remote sensing by satellites and by acoustics should be used where possible. Quality control through validation and calibration protocols and experiments is also important. GIS, various databases, and rapid communication of alarms are other tools for successful monitoring, along with risk analysis and disaster management plans.

The business of models

Accurate prediction is the proof of understanding. Nature's essential processes therefore need to be modelled for the coastal seas. The LOICZ (Land Ocean Interaction in Coastal Zone) project proposes hierarchy of three levels of models.

1 Process models to investigate ecosystem reaction to external forcing
2 Budget models to elucidate mass balances in specific geographic areas and time frames
3 System models to couple regional GCMs to bio-geo-chemical sedimentological or meteorological models

All these should provide inputs to a future Earth System model.

What are the challenges that must be met in integrating models from the natural sciences and those from the social sciences?

A geocentric view of global change sees humans as driving forces of global change, whereas an anthropocentric view of global change considers the environment as one of the drivers of social and economic change. These two aspects are complementary halves of a feedback loop that must be constructed, analysed, and understood together. Thus the anthropocentric, systemic, social science view of global change compliments the geocentric, cumulative, natural sciences view of bio-geochemical cycling. The coastal zones are important for both. It is sometimes suggested that models of these two very different sciences can proceed in one of two ways – either the output of social science models feeds as inputs to bio-geochemical models of coastal change (varying scenarios and projections) or vice-versa. However, the space and time scales are so different that integration of the outputs of one model type as inputs to the other model type is impossible. The challenge, therefore, is to engage both sciences simultaneously to get the scales and the models right.

Socio-economic analysis on land-use change studies[*]

Nelson Lourenço
Universidade Nova de Lisboa, Portugal

Maria do Rosário Jorge; Carlos Russo Machado
Universidade Atlântica, Portugal

Understanding the dynamics of land-use change is a scientific challenge of considerable importance to humanity. The demands for improved knowledge of environmental processes and the impacts of policy on their dynamics must increase, as population pressures on food supplies and natural resources mount and the publicly held perception of preserving environmental diversity and amenity strengthens.

Some of the most profound changes in the landscape have arisen from direct decisions by man concerning land use, and these have affected both the quality of environmental resources and the sustainability of food production. Land-use decisions are based on opportunities and constraints affected by both biophysical and socio-economic drivers. Predicting future land-use change requires methodologies that integrate understanding of the processes affected by these drivers. Because the dynamics of land use and land cover can have biophysical, social, economic, or ecological drivers, we must use an interdisciplinary approach to analyse the different problems. Lest the work depart from the disciplinary perspective of traditional land-use studies it must maintain the specificity of each science.

Land-use change being one of the main issues integrating the debate on sustainable development, its analysis clearly demands an integration of spatial/biophysical data with the socio-economic data. This paper deals with the identification of the required conditions for a real integration of disciplines, without which an integrated analysis may not be possible.

Integration underpins the success of the policy-making process and aids in defining research priorities relevant to policy decisions. It needs to involve the concerned stakeholders: for example, landowners and agricultural managers, local and national regulators, planners and governments, local and national pressure groups, the private and entrepreneurial sector, and the wider public.

The majority of studies tend to concentrate on the effect and impact of man's actions on the environment, dedicating little attention to the consequences of those changes on human activity. Studies on the role which humanity plays in global change are often carried out within the concept of an *analysis of the human dimension*. Thus, they lose the systemic perspective which considers society as a sub-system interacting with the natural sub-system within the far-reaching and integrated framework which is the global change system (Mesarovic et al. 1996). The use of this systemic perspective allows the complexity of the interactions defined by the social and natural systems to be incorporated in the analysis and prompts the development of a different view on the relationship of these two systems. In other words, the social systems are changed at the same time as they modify the natural system.

It is assumed that the reactions of the different land users will largely determine the impact of the policies in terms of constraints and opportunities for development. This conceptual approach should take into consideration the external driving forces, the general framework of measures which direct and rule society's intervention in nature.

Attempts at assessing environmental and policy change impacts on the sustainability of land-use systems in Europe have traditionally followed two approaches.

1 'Disciplinary approaches', developed from the perspective of a single discipline and using terms of reference and techniques most acceptable to that discipline, often with only a limited consideration of broader influences.
2 'Generic approaches', developed primarily within the impacts' community, which attempt to provide forecasts of likely scenarios that encompass the dynamics of complex systems.

Whilst disciplinary approaches provide scientifically exact methodologies for constructing robust frameworks within which assessments of sustainability and policy impacts may be carried out, they often underestimate the range of variability associated with complex systems. Conversely, the generic approaches attempt to encompass the breadth of complex systems, yet often lack the robust methodologies and process descriptions required to accurately forecast future changes, often failing even to predict the current observed variability.

The multi-disciplinary approach departs significantly from existing research addressing similar

[*]This is an abridged version of the paper presented by Prof. Nelson Lourenço at the Meeting of Experts held on 22 February 1999. The unabridged version is available at www.teriin.org

issues. Existing approaches distinguish between the biophysical and economic (Carter et al. 1994), reflecting both the disciplinary perspective of researchers and the difficulty in attracting funding from traditional sources when addressing cross-disciplinary research. The unified approach will more adequately address sustainability in terms of 'cost-benefit' analysis by developing a common baseline for both the economic and the physical attributes of the landscape. Furthermore, this baseline approach will allow a numerical appraisal of the concept of sustainability, which traditionally has been difficult to quantify (Pearce 1993). In addition, efforts will be made to incorporate social science research and stakeholder inputs, which cannot readily be translated into model form.

Another issue relevant to this kind of analysis is the integration of different scale analysis. If we search for answers at local level we must not forget the external driving forces in other levels of intervention, i.e., the regional and the global framework that influences the local or the individual level.

The issue of spatial scales is approached from a different perspective. It is current opinion that aggregation and desegregation between the smallest spatial unit of production decision-making in the landscape allows different spatial scales to be achieved. This is a conceptually coherent approach, given that aggregation can result in information loss. Furthermore, it allows the effects of large-scale phenomena, for instance shifts in market orientation or weather patterns, to be addressed through an assessment of modifications induced at the lowest scale of production.

For the integration of the socio-economic perspective in the study of land-use changes, it is not enough to collect socio-economic data and present its spatial pattern of distribution or even its combination with spatial data. The integration of different disciplines requires the close collaboration between these disciplines, even at the stage of defining the datasets needed.

The information to be collected depends on the questions each scientific perspective has to the same object, i.e., land-use change, and also on the scale of analysis. Based on the definition of the problems, each scientific approach has to identify the questions it may deal with as a contribution to this explanation. A dialog is necessary for the understanding of the different questions and of how the different approaches may contribute to each other's development within the subject.

References

Carter T R, Parry M L, Harasawa H, Nishioka S. 1994
IPCC Technical Guidelines for Assessing Climatic Change Impacts and Adaptations. IPCC-WMO-UNEP.

Mesarovic M, Mcginnis D, and West D. 1996
Cybernetics of Global Change: Human Dimension and Managing of Complexity. MOST Policy papers 3. UNESCO: Paris.

Pearce D W. 1993
Economic Values and the Natural World. London: Earthscan.

The European Union experience on groundwater vulnerability assessment and mapping*

João Paulo Lobo-Ferreira
Dr.-Ing., Head of the Groundwater Research Group,
Laboratório Nacional de Engenharia Civil, Portugal

Introduction

In February 1991, the groundwater group of the ECC (European Community Commission) met in Brussels with the purpose of establishing an international agreement on common methodologies for the elaboration of a groundwater resource inventory for all member states. Such an inventory had been made between 1979 and 1981 for all countries that were members states at the time, but needed to be updated to include new members states. It was decided at the meeting to uniformize the criteria and procedures used by each member state to evaluate, rank, and map groundwater pollution vulnerability.

Groundwater vulnerability

The term vulnerability has been defined and used before in the area of water resources, but within the context of system performance evaluation. Hashimoto et al. (1982) present an analysis of system performance which focuses on system failure. They define three concepts that provide useful measures of system performance (1) how likely the system is to fail is measured by its *reliability*, (2) how quickly the system returns to a satisfactory state once a failure has occurred

*This is an abridged version of the paper presented by Dr João Paulo Lobo-Ferreira at the Meeting of Experts held on 22 February 1999. The unabridged version is available at www.teriin.org is expressed by its *resiliency*, and (3) how severe the likely consequences of failure may be is measured by its *vulnerability*. This concept of vulnerability defined in the context of system performance may also be used in the context of groundwater pollution if we replace 'system failure' with 'pollutant loading'. The severity of the consequences are measured in terms of water quality deterioration, regardless of its value as a resource.

However, the concept of vulnerability has not yet been unambiguously defined in the context of groundwater pollution, and the term has been used to mean different things. Often, the term 'vulnerability to pollution' is used with a composite meaning that would perhaps be better described by risk of pollution.

The authors propose that groundwater vulnerability to pollution be defined, in agreement with the conclusions and recommendations of the international conference on 'Vulnerability of Soil and Groundwater to Pollutants', held in 1987 in The Netherlands (van Duijvenbooden and van Waegeningh 1987), as *the sensitivity of groundwater quality to an imposed contaminant load, which is determined by the intrinsic characteristics of the aquifer* (which are relatively static and mostly beyond human control).

Suggested system of vulnerability evaluation and ranking

Given the definition of vulnerability, it is important to recognize that the vulnerability of an aquifer will be different for different pollutants. For example, groundwater quality may be highly vulnerable to the loading of nitrates at the surface, originated in agricultural practices, and yet be little vulnerable to the loading of pathogens.

Thus, it is scientifically most sound to evaluate vulnerability to pollution in relation to a particular class of pollutant and create specific vulnerability maps. Alternatively, vulnerability mapping could be performed in relation to groups of polluting activities, such as unsewered sanitation, agriculture, and particular groups of industries. As there will generally be insufficient available data to perform specific vulnerability mapping, it is necessary to adopt a mapping system that is simple enough to apply the data generally available, and yet is capable of making best use of those data in a technically valid and useful way. Various such systems of vulnerability evaluation and ranking have been developed and applied in the past.

Some of the systems for vulnerability evaluation and ranking include a vulnerability index which is computed from hydrogeological, morphological, and other aquifer characteristics in some well-defined way. The adoption of an index has the advantage of, in principle, eliminating or minimizing subjectivity in the ranking process. Given the multitude of authors and potential users of vulnerability maps in ECC countries, Lobo-Ferreira and Cabral (1991) suggested that a vulnerability index be used in the vulnerability ranking performed for ECC maps. The DRASTIC index, developed by Aller et al. (1987) for the USEPA (US Environment Protection Authority) has been adopted in the US, Canada, and South Africa. This index has the characteristics of simplicity and usefulness. The DRASTIC index method is briefly reviewed below.

The index of vulnerability DRASTIC

The index of vulnerability DRASTIC corresponds to the weighted average of seven values corresponding to seven hydrogeologic parameters. In Table 1 the DRASTIC parameters and the weights for normal DRASTIC applications and for DRASTIC pesticide applications are presented.

A value between 1 and 10 is attributed to each parameter, depending on local conditions. High values correspond to high vulnerability. The attributed values are obtained from tables which give the correspondence between local hydrogeologic characteristics and the parameter value. Next, the local index of vulnerability is computed through multiplication of the value attributed to each parameter by its relative weight and adding up all seven products. Thus, each parameter has a predetermined, fixed, relative weight that reflects its relative importance to vulnerability. The most significant factors have weights of five; the least significant a weight of one. A second weight has been assigned to reflect the agricultural usage of pesticides. The minimum value of the DRASTIC index is, therefore, 23 and the maximum value is 226. Such extreme values are very rare, the most common values being within the range 50 to 200.

TABLE 1 Weights for DRASTIC parameters

	DRASTIC	
Parameters	Normal	Pesticide
Depth to the water table	5	5
Net **R**echarge	4	4
Aquifer material	3	3
Soil type	2	5
Topography	1	3
Impact of the vadose zone	5	4
Hydraulic **C**onductivity	3	2

Conclusions

The vulnerability evaluation procedure should correspond to a well-defined computation of an index, in order to minimize subjectivity involved in the ranking. The system applied to the ECC countries in the 1970s represented a pioneer effort, which regardless of its merit, allowed for subjectiveness in the evaluation process. This limitation was emphasized in the conference on ‘Vulnerability of Soil and Groundwater to Pollutants’. To overcome these limitations and in order to guarantee the compatibility and coherence of the various national databanks, the authors suggest that vulnerability ranking be made through a well-defined computation leading to a final index. Such an index should meet the requirements of being relatively simple, given the limitations of generally available data, while being technically sound and valid for vulnerability classification. One existing index that meets these requirements, is the index DRASTIC.

References

Aller L, Bennet T, Lehr J H, Petty R J. 1987
DRASTIC: a standardized system for evaluating groundwater pollution potential using hydrogeologic settings. USEPA Report 600/2-85/018.

van Duijvenbooden W and van Waegeningh H G. 1987
Vulnerability of Soil and Groundwater to Pollutants. Proceedings and Information No. 38 of the International Conference held in The Netherlands, in 1987, TNO Committee on Hydrological Research, Delft, The Netherlands.

Hashimoto T, Stedinger J R, and Loucks D P. 1982
Reliability, Resiliency, and Vulnerability Criteria for Water Resource System Performance Evaluation. *Water Resources Research* 18(1):14–20.

Lobo-Ferreira J P and Cabral M. 1991
Proposal for an Operational Definition of Vulnerability for the European Community’s Atlas of Groundwater Resources, in Meeting of the European Institute for Water, Groundwater Work Group Brussels, February 1991.

Panel discussions

Two panel discussions followed after the technical session at the ‘Meeting of experts on coastal development issues’. During the discussions, the panellists agreed that the term ‘hot spots’ could be very confusing and felt it would be better to use the phrase ‘coastal vulnerability’ to development pressures.

The discussions can be summarized under the following themes.

- Coastal vulnerability: constituents and drivers
- Mechanisms through which the driving forces impact the environment
- Possible ways of mitigating/avoiding the development of coastal vulnerability

Coastal vulnerability: constituents and drivers

Two main types of hot spots can be identified (1) anthropogenic or artificial, i.e., those created by societal pressures and (2) natural, i.e., those vulnerable due to their intrinsic characteristics, which are beyond human control and most vulnerable to human intervention.

A potential hot spot or an already degraded area would have one or more of the following characteristics.

- An intrinsic vulnerability arising from the fact of the area being low lying, tectonically unstable, prone to erosion/sedimentation.
- Fragile ecosystems such as coral reefs, mangroves, sand dunes, wet lands, and estuaries.
- Heavy pollutant loading from human activities.
- Development activities that use up coastal resources faster than their regeneration capacity.

Some drivers of relevance in the Indian context identified by the panellists include mining of sand and coral reefs, industrial activity, construction activity, fishing, tourism, intensive agriculture and aquaculture, livestock rearing, chemical industries, power plants, and endogenous population growth.

Relevant mechanisms

Mechanisms through which the driving forces impact the environment include type of technology used, socio-economic setting, resource institutions, deficient policy formulation, weak enforcement of rules and regulations, lack of monitoring, market economy, and demographic changes.

Preventive steps

Possible steps to mitigate/avoid the development of coastal vulnerability include (1) reserve areas or zones, and work with a conservation plan with controlled anthropogenic activity; (2) develop marine parks and sanctuaries; (3) create alternative income generating options for those dependant on coastal resources; (4) create incentives in the form of reduced tariffs, subsidies, etc., to use alternatives to sensitive coastal resources such as sand and coral; (5) have regulatory mechanisms to monitor programmes; (6) enforce rules and regulations; (7) educate stakeholders and create awareness among them; (8) undertake research and disseminate results; (9) identify coastal districts for future development; and (10) develop policy and ban use of scarce resources.

These responses could be achieved through (1) participatory bottom-up planning process; (2) integration of socio-economic and environment data to facilitate planning; (3) capacity building programmes for institutions and government; (4) application of GIS (Geographical Information System) and remote sensing techniques; and (5) identification of geographically fragile and biodiversity sensitive areas and prioritizing the issues of concern accordingly.

The panellists concluded that there is need for prioritizing and identifying critical areas first. They agreed that this would be a difficult task, considering that the nature of the problems differs across distance.

The expert group and the subsequent session by the main researchers of the project arrived at the following main drivers of importance to coastal India: tourism, industrialization, urbanization, intensive agriculture and aquaculture, and port activity.

List of participants

Mr Amjad Abdulla
Coastal Engineer
Ministry of Home Affairs, Housing and Environment
Environment Research Centre
Huravee Building
Ameeru Ahmed Magu
Male 20-05
Republic of Maldives
Tel. 960 324861
Fax 960 324739
E-mail indoex@environment.gov.mv

Dr S A H Abidi
Director/Vice Chancellor
Central Institute of Fisheries Education
Indian Council Agricultural Research
Seven Bungalows
Yari Road, Versova
Mumbai – 400 061, India
Tel. +91 22 6363404
Fax +91 22 6361573
E-mail cife@x400.nicgw.nic.in
fishinst@bom3.vsnl.net.in

Dr Claude Alvares
Goa Foundation
Above Mapusa Clinic
Mapusa, Goa, India
Tel. +91 832 263 306
Fax +91 832 263 306
Email obis@bom2.vsnl.net.in

Dr Anjali Bahuguna
MWRD/RESA,
Space Application Centre
Jodhpur Tekra, Ahmedabad
Gujarat, India
Tel. +91 79 674 0256
Fax +91 79 676 0626
E-mail anjali@sac.ernet.in

Prof. D V Borkar
Registrar
Goa University
Goa – 403 006, India
Tel. +91 832 221 375/6/221347
Fax +91 832 221 348
E-mail registra@unigoa.ernet.in

Dr A G Chachadi
Department of Geology
SPO, Goa University
Taleigao Plateu – 403 205, India
Tel. +91 832 221 375/221 346/7 extn. 258
Fax +91 832 224 184
E-mail chachadi@unigoa.ernet.in

Dr Adelino Rodrigues Da Costa
Delegate, Fundacao Oriente
Fontainhas, Panaji
Goa, India
Tel. +91 832 230 728
Fax +91 832 230 291

Dr João Paulo Lobo-Ferreira
Laboratorio Nacional De Engenharia Civil
Depto. De Hidraulica
Avenida Do Brasil 101
1799 Lisboa Codex
Portugal
Tel. 351 1 848 21 31
Fax 351 1 847 38 45
E-mail lferreira@lnec.pt

Dr Sujata Gupta
TERI
Darbari Seth Block
Habitat Place
Lodhi Road
New Delhi – 110 003, India
Tel. +91 11 460 1550/462 2246
Fax +91 11 462 1770/463 2609
E-mail sujatag@teri.res.in

Prof. V Guruswamy
GTZ Project Coordinator
Institute of Remote Sensing
Anna University
Chennai – 600 025
Tamil Nadu, India
Tel./Fax +91 44 235 3873
E-mail iom-mdrs@x400.nicgw.nic.in

Dr Nandakumar Kamat
Botany Department
Goa University
Goa – 403 006
Tel. +91 832 221375-6/221347 extn. 254
E-mail nkamat@unigoa.aditya.ernet.in

Ms Saltanat Kazi
TERI
Western Regional Centre
Models Residency
Block 7, G – 6
Near St. Inez Church
Panaji, Goa – 403 001, India
Tel. +91 832 425 290
E-mail terigoa@goa1.dot.net.in

Mr Sudhir Khalwadekar
TERI
Western Regional Centre
Models Residency
Block 7, G - 6
Near St. Inez Church
Panaji, Goa – 403 001, India
Tel. +91 832 425290
E-mail terigoa@goa1.dot.net.in

Mr P D Kunte
National Institute of Oceanography
Dona Paula, Goa – 403 004, India
Tel. +91 832 226 253 extn. 4436
Fax +91 832 223 340
E-mail kunte@csnio.ren.nic.in

Prof. Nelson Lourenco
Universidade Nova De Lisboa
Socinova
Gabinete De Investigacao Sociol. Apl.
Avenida De Berna 26-C, 1050 Lisboa, Portugal
Tel. 351 1 793 35 19
Fax 351 1 797 77 59
E-mail nelson@mail.eunet.pt

Dr Jordi Marturia
Instituto Cartografic De Catalunya
Parc de Montjuic, 08038 Barcelona, Spain
Tel. 34 3 425 29 00
Fax 34 3 426 74 42
E-mail jmarturia@icc.es

Dr Antonio Mascrehnas
National Institute of Oceanography
Geology Division,
Dona Paula, Goa – 403 004, India
Tel. +91 832 226253 Ext. 4336
Fax +91 0832 223340
E-mail antmas@csnio.ren.nic.in

Mr Rakesh Metha
Development Commissioner
Government of Goa
Tel./Fax +91 832 225 332

Dr D Mohan
Scientist 'C'
DOD, ICMAM
Directorate, Koodal building, II nd floor
Anna University Campus, Chennai – 600 025
Tamil Nadu, India
Tel. +91 44 230 1854
Fax +91 44 230 1864
E-mail mohan@icmam.tn.nic.in

Ms Indrani Nagar
TERI
Darbari Seth Block, Habitat Place
Lodhi Road, New Delhi – 110 003, India
Tel. +91 11 460 1550/462 2246
Fax +91 11 462 1770/463 2609
E-mail indrani@teri.res.in

Dr G N Nayak
Department of Marine Science
and Marine Biotechnology
Goa University, Goa – 403 006, India
Tel. +91 832 221 375 6/221 347 extn. 262
Fax +91 832 224 184
E-mail gnnayak@unigoa.ernet.in

Dr Ligia Noronha
TERI
Western Regional Centre
Models Residency, Block 7, G – 6
Near St. Inez Church, Panaji
Goa – 403 001, India
Tel. +91 832 425 290
E-mail terigoa@goa1.dot.net.in

Dr R K Pachauri
Director
TERI, Darbari Seth Block, Habitat Place
Lodhi Road, New Delhi – 110 003, India
Tel. +91 11 460 1550/462 2246
Fax +91 11 462 1770/463 2609
E-mail pachauri@teri.res.in

Dr P S Raikar
Department of Geology
Goa University, Goa – 403 006, India
Tel. +91 832 221 375/221 346/221 347 Extn. 258
Fax +91 832 224 184

Mr Harun-or Rashid
Project Director
Coastal Fisheries Management Project
Government Building No. 1
Agrabad, Chittagong, Bangladesh
Tel. 88 31 720 824
Fax 88 31 721 731
E-mail Falcon@spnetctg.com

Gen. S L Rodrigues (Retd)
Executive Director
The International Centre Goa
Goa University Road, NIO Post Office
Dona Paula, Goa – 403 004, India
Tel. +91 832 231 533/4
Fax +91 832 231 532
E-mail goa@bom2.vsnl.net.in

Dr Ehrlich de Sa
Director
National Institute of Oceanography
Dona Paula, Goa – 403 004, India
Tel. +91 832 221 352-3
Fax +91 832 223 304

Prof. Jay S Samant
Head
The School of Environmental Sciences
Shivaji University
Kolhapur – 416 004, India
Tel. +91 231 655 571 extn. 5304
Fax +91 231 656 133

Mr R A D B Samaranayake
Manager, Coastal Resource Development
Coast Conservation Department
Maligawatte, New Secretariat
Colomba 10, Sri Lanka
Tel. 941 449 754–7
Fax 941 438 005
E-mail mobocogh@sri.lanka.net

Ms Kavita Singh
Info. Tech. Group
National Institute of Oceanography
Dona Paula
Goa – 403 004, India
Tel. +91 832 226 253
Fax +91 832 223 304
E-mail ksingh@csnio.ren.nic.in
ksingh@darya.nio.org

Dr Kalidas Sawkar
National Institute of Oceanography
Dona Paula, Goa – 403 004
India
Tel. +91 832 226 253 extn. 4436
Fax +91 832 223 304
E-mail kalidas@csnio.res.nic.in

Ms Sangeeta Sonak
TERI
Western Regional Centre
Models Residency, Block 7, G – 6
Near St. Inez Church, Panaji
Goa – 403 001, India
Tel. +91 832 425 290
E-mail terigoa@goa1.dot.net.in

Dr S Sreekesh
TERI
Darbari Seth Block
Habitat Place, Lodhi Road
New Delhi – 110 003
India
Tel. +91 11 460 1550/462 2246
Fax +91 11 462 1770/463 2609
E-mail sreekesh@teri.res.in

Mr Mohamed Zuhair
Assistant Environment Analyst
Ministry of Home Affairs,
Housing and Environment
Huravee Building
Ameeru Ahmed Magu
Male 20-05, Republic of Maldives
Tel. 960 331724
Fax 960 324739
E-mail env@environment.gov.mv

Future issues will contain the following

- Updates on the project
- A theme paper on coastal development issues
- Summaries of recent literature on project related subjects
- Forthcoming events and meetings in India and the EU relating to coastal issues

Editorial Team

Editor Maria Ligia Noronha
Associate Editors S Sreekesh, S Sonak
Assistant Editor J Ram Mohan

Published by TERI on behalf of all Indian and EU partners and printed at Type Prints, 9607/13, Multani Dhanda, Paharganj, New Delhi – 110 055