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Symposium: Geomorphology and Environmental Impact Assessment

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GEOMORPHOLOGY AND ENVIRONMENTAL IMPACT ASSESSMENT: AN INTRODUCTION

A few considerations concerning the state and contribution of geomorphology to the process of Environmental Impact Assessment are presented here as an introduction to the Symposium papers. The following issues will be commented briefly:

- Actual presence of geomorphology in the existing norms and regulations as well as in the current practice.
- General conceptual framework.
- The problem of quantifying the assessments.
- Impact prediction and audits.

GEOMORPHOLOGY IN EIA REGULATIONS AND PRACTICE

A survey of the situation with respect to the presence of geomorphology in EIA regulations in some European countries (Rivas & *alii*, 1995) showed that they do not usually incorporate explicitly the consideration of geomorphological factors and processes; in some cases, however, geomorphological characteristics are implicitly included in the reference to other environmental components. (Wathern, 1990) The same is true to a great extent in the case of existing practices. Manuals describing EIA methods and procedures often disregard, or consider very superficially, geomorphological factors, even in the case of projects which may imply important modifications of landforms, deposits or geomorphological processes (Dept. of the Environment, 1989; Claver, 1991). Some interesting examples of proposals for the evaluation of the effects of different types of projects on geomorphological characteristics (Matas & Pérez del Campo, 1990; Díaz de Terán & *alii*, 1992) exist; however, they are usually in the form of specific studies contained in volumes dealing with earth science matters and not in the wider framework of environmental studies.

This limited presence of geomorphology in EIA studies is probably due to three main causes. Firstly, geomorphology is often not perceived as «important» or «sensitive» to human influence by the non-geomorphological or non-earth science community; the sensitivity and concern with respect to living organisms are well developed among profesionals, decision makers and general public, but not with respect to geomorphologial characteristics, which tend to be considered by non-specialists as permanent features of the landscape.

Secondly, the geomorphological community, and earth science community in general, have traditionally not shown a strong interest on environmental issues. The participation of geomorphologists in the general environmental debate, the rising and development of movements for the conservation of the geomorphological heritage and similar actions, have appeared later and are certainly not as intense and widespread as equivalent efforts coming from the life, water or atmosphere science communities. Even though very valuable examples of volumes devoted to geomorphology and environmental problems have been available for more than two decades (Flawn, 1970; Cooke & Doornkamp, 1990; Panizza, 1996), they represent a proportion of the geomorphological literature which is clearly smaller than in the case of the biological sciences. The same is true when it comes to journals; a survey of the journals referenced in the Science Citation Index shows that only two journals with an «environmental» title appear in the sections on geosciences, geology or geography, totalling nearly 150 titles. In the field of environmental sciences, only 2 titles out of 96 explicitly mention geoscience.

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Of course, papers on geomorphology and environmental impacts appear in several of the journals contained in both lists.

The third reason, probably a consequence of the one above, is the limited development of tools specifically designed to facilitate the assessment of the effects of human activities on geomorphological features, within the general framework of EIA. This is also due in part to the fact that EIA is normally conceived as an instrument to analyze the effects of specific actions, whereas geomorphological features are more suitable for consideration in relation to changes in land use affecting areas wider than in the case of single projects. Geomorphological impact assessments would be more useful for the evaluation of plans (Rivas & *alii*, 1994; González & *alii*, 1995) but EIA is frequently not required for these.

The eighteen papers presented to this Symposium are a good sign of the rising interest on the application of geomorphology to EIA. It is to be hoped that these and future contributions will provide the basis for better assessments - and mitigation- of the effects of human activities on geomorphological features and on the environment in general.

CONCEPTUAL FRAMEWORK

The general interactions between human activities and geomorphological environment are represented in figure 1 (Panizza, 1990; Cendrero, 1995a). As shown in the figure, impacts on the natural environment result from activities aimed at the exploitation of geomorphological and other resources; but the geomorphological environment also produces impacts on the human environment, through processes which can be hazardous. That is, the geomorphological environment as well as human beings and structures can play both an active and a passive role with respect to impacts, depending on the circumstances (Cavallin & *alii*, 1994; 1996).

Taking the simplified relationships described above as a basis, different geomorphological «components» of the environment can be identified. Those components are elements or parts of the environment which can experience

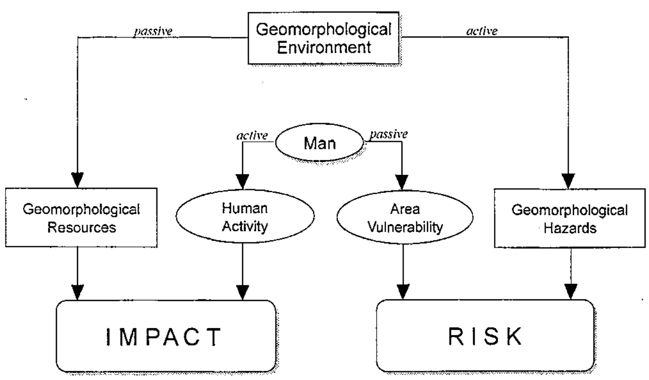

FIG. 1

different types of impacts that can be analyzed separately. Two main groups of components can be considered: geomorphological assets (materials and landforms) and geomorphological processes (Rivas & *alii*, 1997). Geomorphological assets include:

– Consumable geomorphological resources, such as sand, gravel peat, etc, which are exploited as raw materials, for construction or for use as fertilizers.
– Non-consumable assets:
  sites of geomorphological interest;
  landforms as geomorphological components of the landscape;
  geomorphological units which are an essential support of certain ecosystems.

The types of relationships between those components and human activities vary considerably and so does the possibility to assess their potential environmental consequences.

As environmental impact assessments imply the formulation of predictions concerning the effects of human interventions on the environment, a better integration of geomorphology into the EIA process would require the development of methods to make such predictions and to express them, if possible, in a quantitative way, so that they can be tested and verified independently. This is not always possible in the present state of knowledge and it is one of the lines of work in which improvements are needed.

The problem of making reliable predictions for EIA is particularly acute in the case of geomorphological processes (Brunsden, 1996). In some cases it is possible to use modelling or parametric approaches to predict the consequences of certain interventions (Amarú & van Asch, 1996; Amarú & *alii*, 1996; Rivas & *alii*, 1996). However, in most instances predictions can only be formulated in general, qualitative terms; this is in part due to limitations in the knowledge concerning the role of different factors in the development of geomorphological processes and in part to the fact that in most actual EIA studies the necessary baseline data are not available or cannot be obtained because of the limited time and/or resources.

THE PROBLEM OF QUANTIFICATION

As mentioned above, there is a need to develop tools for quantifying the formulation of impact assessments on the geomorphological environment. Strictly speaking, quantification should imply the expression of geomorphological characteristics by means of magnitudes with specific dimensions. Those characteristics could thus be measured objectively, their baseline condition determined unambiguously and changes experienced by them (actual or predicted) described in terms which could be verified by any operator.

In some cases, for instance consumable geomorphological resources or geomorphological components of the landscape, indicators and indices for expressing impacts in terms of magnitudes with specific dimensions have been made (Patrono & *alii*, 1996; Rivas & *alii*, 1997). In other cases this is not possible, even at the theoretical level; this is the case of impacts on sites of geomorphological interest (SGI). The «value» or «interest» of an SGI cannot be measured but it can be expressed numerically, using methods and applying criteria which are transparent and replicable by any operator (Rivas & *alii*, 1997). In this case, even though the criteria may not be accepted by everyone, once they are accepted and applied any observer should arrive at the same results.

In the case of geomorphological assests we are dealing with geomorphological features which are essentially «static» and play a passive role; but the situation is very different with respect to geomorphological processes, which are «dynamic» and play both passive and active roles and usually react in response to changes introduced by human actions. figure 2 (Cavallin & *alii*, 1996) shows the types of relationships between geomorphological environment and human activities; two main possibilities can be considered:
a) Geomorphological assets in relation to human activity, where the geomorphological environment is regarded as mainly passive in relation to people (active); in other words, an asset/resource may be altered or destroyed by human activity;
b) Geomorphological hazards in relation to the vulnerability of an area, where the geomorphological environment is regarded as mainly active in relation to human activities; a hazard may alter or destroy some buildings or infrastructures. Moreover, projects may also modify geomorphological processes and thus the hazards and risks derived from them.

Quantification is certainly more difficult in the latter case. Do we have deterministic models to make reliable predictions concerning those types of interactions as well as the necessary data to apply them?. There are processes for which this is possible at both the theoretical and practical levels; the safety factor can be calculated for a slope in its pre- and post-project condition and this may be a satisfactory way to express impacts on slope stability in a quantitative manner. In other instances theoretical or empirical models allowing reasonable predictions are available, as in the case of soil erosion, but baseline data on the pre-project condition of the area are often not available -nor can be obtained within the limitations of most EIA studies- and quantitative predictions on the post-project effects may not be possible in actual practice. For many other processes our ability to make predictions is still basically at a qualitative level.

It is obvious that the key for better EIA on geomorphological processes is the improvement of our basic understanding of such processes. The development of better deterministic models will enable the formulation of more precise and reliable predictions on the effects of changes on the different factors.

One of the problems inherent to EIA is evaluating the importance of a given impact or comparing the level of impact among several alternatives (sites, routes, projects). This is true for both environmental impacts in general and for geomorphological impacts in particular. A possible approach to solve this problem is the use of integrated indices which summarize a series of characteristics and provide a «measure» of environmental quality.

To develop integrated indices of this kind a series of issues have to be addressed (Mohr, 1988):
– finding the appropriate variables/indicators;
– limiting the analysis to the most relevant ones;
– assessing their state/condition;
– common scaling of variables expressed by means of, heterogeneous units;
– weighting the relative importance of the individual variables.

Geomorphologists should devote more efforts to address those issues and provide useful tools and criteria for standard EIA practices.

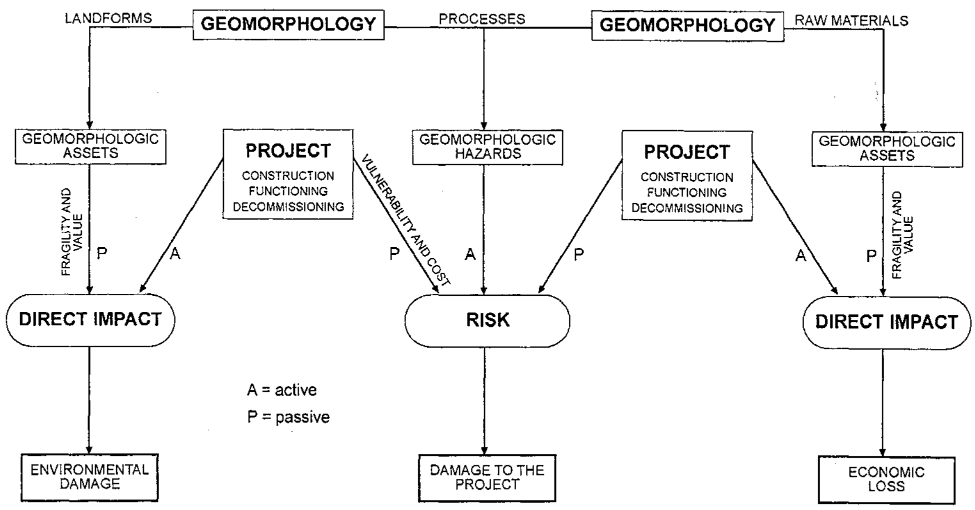

FIG. 2

PREDICTION AND AUDITS

The design and application of quantitative instruments for the assessment of environmental impacts is certainly easier in the case of post-intervention audits than for the usual EIA studies, which imply the formulation of predictions on the behaviour of geomorphological processes if some changes are introduced.

Audits of the geomorphological impacts of human activities, be it especific projects, plans, programmes or policies, can in general be carried out satisfactorily as long as two conditions are met: a) unequivocal indicators and indices are established for the description of changes experienced by the different geomorphological features; b) baseline data on the pre-intervention condition exist or can be obtained using standard instruments and sources (air photographs, sediment or archive records, etc). The two conditions can often be fulfilled in the case of geomorphological assets, but not when it comes to geomorphological processes. Predictions, especially for geomorphological processes, are more difficult.

Another problem concerning EIA for specific actions is that the effects on geomorphological assets and processes of a single project may not be relevant unless they are considered in a wider context. Important modifications of the geomorphological environment may result from a series of individual interventions which are part of the general land-use change pattern in an area (Douglas, 1997; Webb & Morton, 1997). The usual EIA instruments for individual projects may thus not be suitable for analyzing these effects.

The application of integrated indices offers a possibility to better assess impacts for both post-project audits and pre-project predictions. A proposal for an index that can be used to describe the condition of SGI's and to assess impacts on them has been presented by Rivas & *alii* (1997). It would be desirable to improve this type of index and to develop others for different geomorphological aspects and for the combination of geomorphological assessments with assessments of other environmental components. But geomorphology can also help integrating different environmental components into a single environmental quality index which can be used to assess past and future changes. The use of morphodynamic units as a basis for the calculation of «environmental quality» and «use-developmemt potential» indices, combining geomorphological and other environmental components has been proposed by Cendrero (1995b) and Cendrero and Fischer (1997). These indices can be used independently or combined by means of a «conservation-development diagram» (figure 3), especially for auditing the combined effects of projects and plans in a given area, but also for the identification of sensitive units or, in some cases, for impact prediction in the context of EIA studies.

DEVELOPMENT OF THE SYMPOSIUM

A total of 22 contributions have been presented to this Symposium, including 5 oral papers and 17 posters. The five oral papers addressed different issues concerning the

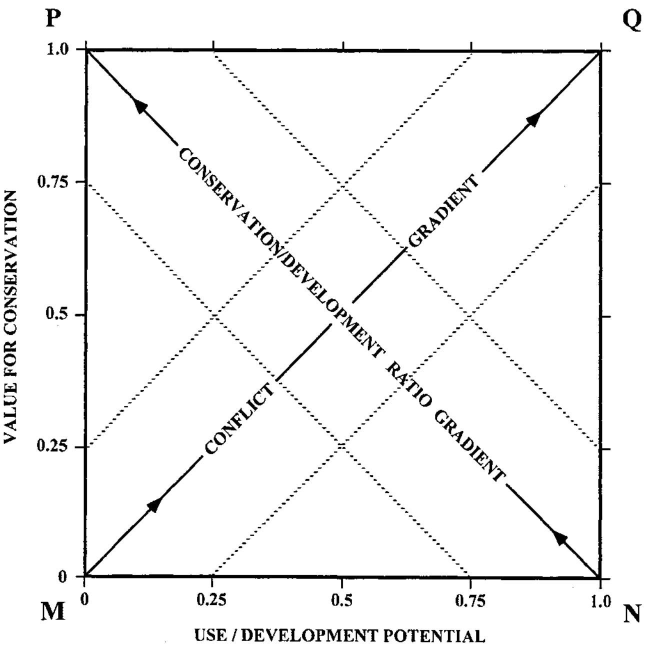

FIG. 3

role of Geomorphology in Environmental Impact Assessment studies.

The first paper, presented by F. Baraldi, D. Castaldini & M. Marchetti, concerns the «Geomorphological Impact Assessment in the River Mincio Plain (Province of Mantua, Northern Italy)». This research analyzed landscape modifications induced by human activity in the past 40 years; this sector of the Po plain has been subject to intense quarrying activities, which have caused relevant landscape changes.A methodology for the assessment of the scientific quality of landforms was applied. The impact on landscape is defined on the basis of the reduction in scientific quality due to the degree of damage produced by people's activity.

D. Schaub, C. Wuthrich & C. Seiberth presented the contribution «How landscape features influence sediment yields (a comparison of two investigation areas in northwest Switzerland)». A long-term investigation on nonpoint-source pollution of water courses due to soil erosion has been conducted in two intensively used agricultural areas. The field researches have been carried out at three scales: the test plot scale, the field scale and the catchment scale. Based on the results a simple GIS-incorporated model has been developed. It describes sediment and nutrient fluxes in the catchment scale with the help of statistical relationships between weather conditions, geomorphological features, soil properties, as well as land use and sediment retention functions of different landscape elements.

Another oral paper was presented by A. Laouina concerning «Desertification of Eastern Moroccan steppes; geomorphological aspects». In the area described a wide variety of complex ecosystems coexists which are related to both natural and human factors. The process of desertification in this weakly inhabited region, is linked to the important changes observed in land occupation and in the systems of soil utilisation. The problems of sustainability and choice of properly adapted techniques are discussed.

A.J. Conacher presented the oral paper «Geomorphology and EIA in relation to Agriculture». The effects on the environment of dryland agricultural practice in Australia take place in the soil or affect the soil, with the driving processes being pedological, hydrological and geomorphic in nature: rainwash and salinisation of soil and water, with several implications in relation to EIA. The shortcomings of standard EIA methods for assessing impacts due to this type of activities were pointed out by the author.

The last oral paper on «The floodplains of Northeastern Argentina. Geomorphic components and environmental impacts of flood control projects» was presented by F.O. De Francesco, E.J. Schnack, J.A. Schnack, L.C. García Lozano & U.R. Colado. With the purpose of assessing the impacts of 51 flood control projects, a standard procedure has beens developed and applied in each case, involving impact identification, vulnerability of the proposed project and mitigation measures.

Among the seventeen posters, two analyzed the impacts of specific engineering projects: an electric transmission line in Malaysia, presented by K.B. Osman Salleh, and a container port in Genoa (Italy), presented by R. Terranova, P. Brandolini, M. Fedolino, G. Canepa & A. Ramella. The former described a methodology for selecting a corridor using various environmental and other criteria; the latter discussed the effects of the project on shoreline progression and regression.

Two other posters refered to the impact of coal mining in the regions of Meghalaya, India, and Primorsky, Russia. The first one, presented by R.K. Rai, stressed the various geomorphological problems which occurred, such as land degradation, soil erosion, surface run-off and increase in sediment load. The second one, by L.M. Cruchinina, analysed a wider spectrum of environmental problems, including anthropogenic processes and limitations on the types of economic activities.

Another group of four posters illustrated the problems of the environmental impacts of land use changes, mainly due to agriculture and grazing. One of the posters, presented by M. Ripeanu & I. Mac, concerned agricultural exploitation in Romania and described three distinct situations: deforestation and fallowing, land exploitation, and returning to the «wild» agriculture system. Another poster examined land use change in the inner Alentejo, Portugal and was presented by D. Ferreira; it analyzed different issues concerning the assessment of erosional impacts of land use changes during the XXth Century. A third poster, by L. Gourari & M. Benjelloul, examined erosion witin the context of morpho-bio-climatic and anthropic conditions in the region of An Nokrah, Morocco. The fourth poster, by H. Lavee, P. Sarah & A. Perevolotsky, described the effets of traditional grazing in semiarid areas in Israel; the results of the study show differences in eco-geomorphological characteristics between grazed and ungrazed areas, between seasons and between sites.

Other posters examined the effects of various human activities. F. Li & F. Liu showed the urban landform system structure of a town in China and its formation, planning and construction. G. Veni illustrated aquifer pollution in karst areas of Texas, as a consequence of urbanization. Y. Kurashige, analyzed the source of suspended river sediment after selective logging in a basin in Hokkaido, Japan. The poster by B. Mihai & I. Patru presented a comparative case study in the Carpathian Mountains of Rumania, analyzing two areas with similar morphologic conditions but with different human uses.

Two posters addressed the problems of assessment and conservation of natural resources. The first one, on «Landscape Unit Map of Italy», was presented by V. Amadio, M. Amadei, R. Bagnaia, B. Crescenzi, D. Di Bucci, L. Laureti, A. Lisi, F.R. Lugeri & R. Salvucci: The authors showed that the holistic character of the landscape is linked to geomorphological patterns; therefore, geomorphology appears as a most important tool at this level of landscape study. A natural conservation programme in Rumania, presented by A. Cioaca, described the landforms in the area, grouped by geo-type criteria, and with reference to the geomorphological hazards they are prone to.

The problem of environmental restoration in a densely populated, humid zone was discussed by H. Piégay, G. Bornette, P. Grante & A. Laplace-Dolonde through the case of the river Ain in France.

Finally, two posters dealt with natural hazards. The first one, by D.E. Kapule, concerned a case study of geomorphological hazards in the central Rift Valley, in Kenia; the study shows that hazards are mainly caused by several linear depressions opened during heavy rainfalls. The second, by Z. Kulikova, presented a map of natural hazards in Russia, which may be used for environmental monitoring and risk assessment.

If we refer back to figure 2, we can see that the posters by Amadio & *alii*, by Cioaca and by Piègay & *alii* deal with the analysis of the direct impacts of projects on non-consumable geomorphological assets; the contributions by Kulikova and by Kapule analyse the risks for human activities derived from geomorphological processes. Other posters refer mainly to impacts of various types of activities or projects like engineering works, coal mining, land use change and other umann activities. Finally a series of contributions present analyses which deal with the three types of relationships included in figure 2.

In summary, it can be seen that most papers deal with the description of the effects of human activities on the geomorphological environment or the hazards affecting the former, but very few attempt to make predictions on the impacts which would result from given actions. Quantitative analyses are practically absent; most assessments are at the qualitative level, making it difficult to replicate them or even to evaluate the importance of the impacts described or predicted. If we assume that the sample constituted by the contributions to the Symposium offers a fair representation of the state of international geomorphology in this field, which is not necessarily true, the need to devote more efforts to quantification and prediction is clearly demonstrated.

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