Considerations on the definition of the concept of environmental sensitivity

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We may say generally that an object whether animate or inanimate, is "sensitive" to a certain feature of the environment if it behaves differently according to the presence or absence of that feature.

Bertrand Russell, The analysis of mind

1. According to its most accepted meaning, the notion of "sensitivity" has emerged as a concept linking three elements: a set of effects or consequences, an independent set of conditions and a set of given causes (stresses). The scope of the present considerations is limited to sentences of the type (note that effect, condition and stress mean **sets** of effects conditions and stresses, respectively):

P: The sensitivity of an effect A (a set of effects) to a condition B (a set of conditions) for a given stress C (a set of stresses).

Sensitivity, although the previous sentence suggests a triadic relationship, is a binary concept linking the dependent effect A to the condition B. Correspondingly, the sensitivity analysis can be defined as the study of how effect A varies when condition B changes for a given intensity of a stress C. This conforms with the definition of model sensitivity analysis that is commonly performed to investigate how the variation of the output of a model depends on the values of the model parameters for a given input, if we assume that the output, the parameter values and the input of a model correspond to the effect A, the condition B and the stress C, respectively.

The second step of our investigation consists in defining the elements A, B and C that we have previously introduced as components of the sensitivity notion. It seems almost natural to account for the three categorical elements that are generally considered in the decision making process for the management of the environmental emergencies: the environmental, the social and the economic factors. The concept of environmental sensitivity can be structured by introducing the above elements within the general sentence P. These can be sorted in a number of ways (to be more precise, 3^3=27) such as:

The sensitivity of the environment to the social conditions for a given social stress;

The sensitivity of the environment to the economic conditions for a given social stress;

The sensitivity of the economy to the environmental conditions for a given environmental stress;

Etc.

An analysis of the use of the above sentence in the scientific literature to define the "environmental sensitivity", suggests that there is a certain consensus in classifying as "environmental" any kind of sensitivity analysis for which both conditions B and stress C are of environmental nature, whereas consequences can be also of social and/or economic character. From a mere mathematical point of view, when A and B can be parameterized as dependent and independent variables, we can introduce the function

$$Y = S(X, D) \qquad (1)$$

where Y and X are attributes that measure the intensities of A and B, respectively, and *D* measures the intensity of the stress. If Y is proportional to *D*, equation (1) becomes:

$$Y = S(X) \cdot D \qquad (2)$$

S(X) is the ratio between the effect (Y) divided by the stress (*D*). S(X) can be used to rank the conditions X according to their effects Y. For instance, when an environmental effect (e.g., the concentration of a radionuclide in the lake water) depends on certain condition X of the system (e.g., the mean water retention time) we can rank the environmental systems L_1 (X_1), L_2 (X_2), …L_n (X_n) according to their responses $Y_1 > Y_2 > \ldots . Y_n$ to the given stress (deposition of radionuclide on the lake surface). Generally we say that L_1 is more vulnerable than L_2 that is more vulnerable than L_3, and so on. We say also that the environmental system (e.g., the lacustrine environment) is very sensitive to the considered condition X as the effects significantly vary with this condition.

If we are concerned with the way Y [A] varies with X [B], rather than with the absolute intensity of the effect A, a measure of the sensitivity may be:

$$\frac{\partial S(X)}{\partial X} \qquad (3)$$

or, by normalizing to the ratio X/S(X):

$$\frac{X}{S(X)} \frac{\partial S(X)}{\partial X} \qquad (4)$$

As seen from the previous discussion, we are considering the dependence on the environmental conditions of the intensity of certain effects caused by a given environmental stress. A different definition of environmental sensitivity was suggested by Buckley, 1982: *"The environmental sensitivity of a given environment unit may usefully be defined as the relation between the response of that unit to a given stress, and the severity of the stress"*. It is easily realized, by looking at formulae (1) and (2), that such last definition is somewhat similar to our notion when the relationship of the effects with the environmental conditions are not explicitly emphasized (Y is assumed a function of the stress and X is assumed to be a parameter). The above-mentioned strict definition is often used when non-radiological environmental issues are afforded. However, it seems that, in view of the results of the scientific debate reported in the international literature, this strict definition is not sufficiently developed for the current use in radioecology as we will show in the next section. On the other hand, the Buckley's definition seems to comply with the notion of environmental *vulnerability* that, according to the OECD glossary of statistical terms (http://stats.oecd.org/glossary/detail.asp?ID=2886), is the "measure of the extent to which a community, structure, service or geographical area is likely to be damaged or disrupted, on account of its nature or location, by the impact of a particular disaster hazard" (United Nations, 1997). However, according to the above definition, vulnerability is conceived as a variable rather than a function or, at the most, as a function of the environmental stress. It is important to note that the concepts of "vulnerability" and "sensitivity" are not equivalent. Systems that are very vulnerable to an environmental stress are not necessarily highly sensitive to the variation of certain environmental conditions. On the contrary, systems that are scarcely vulnerable may be highly sensitive to the changes of these conditions (figures 1 and 2).

2. Justification of the concept of sensitivity in view of the a literature review

In radioecology some definitions of the environmental sensitivity or of similar concepts were used.

Firstly, let us consider the definition of Håkanson et al., 1996: A given load (=fallout) of any substance to a given lake may cause very different concentrations in water and biota depending on the characteristics of the lake and its catchment. This sentence can be paraphrased according to the semantic structure of proposition P: the sensitivity of the environmental effect (contamination of water and biota) to the environmental conditions (the characteristics of the lake and of its catchment) for a given environmental stress (a given load of radionuclide = deposition of radionuclide over the lake and the catchment).

A second definition is due to Aarkrog, 1979: time integrated activity concentration of ^{137}Cs and ^{90}Sr in milk (Bq l^{-1} y) per Bq m^{-2} of radionuclide fallout in different regions, however, the sensitivity of an environmental component (contamination of milk) to the different environmental conditions of the selected geographic regions for a given radionuclide fallout.

A third definition (Howard, 2000) accounts for the individual and collective doses for a given radionuclide fallout in different regions and thus, by paraphrasing, the sensitivity of a social effect (the health impact of radiation on man) to the different environmental conditions of the selected geographic regions for a given fallout.

Table 1 summarizes how the categorical elements (the environmental, the economic and the social factors) are encompassed in proposition P for the three previously mentioned definitions.

Table 1. The categorical elements in the general structure of the sensitivity concept in relation to different types of partial definition.

	Terms in sentence H		
Definition	A effect/impact	B conditions	C stress
Håkanson et al., 1996	Environmental	Environmental	Environmental
Aarkrog, 1979	Environmental	Environmental	Environmental
Howard, 2000	Social	Environmental	Environmental

References

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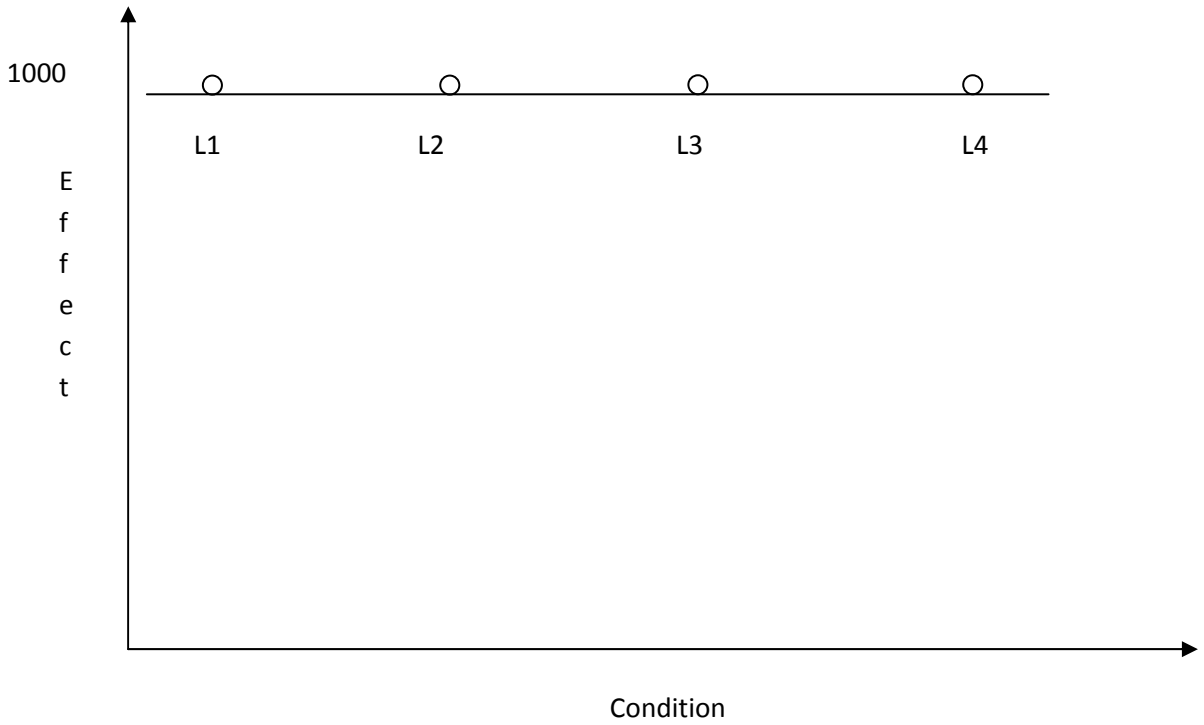

Figure 1. High vulnerability – low sensitivity

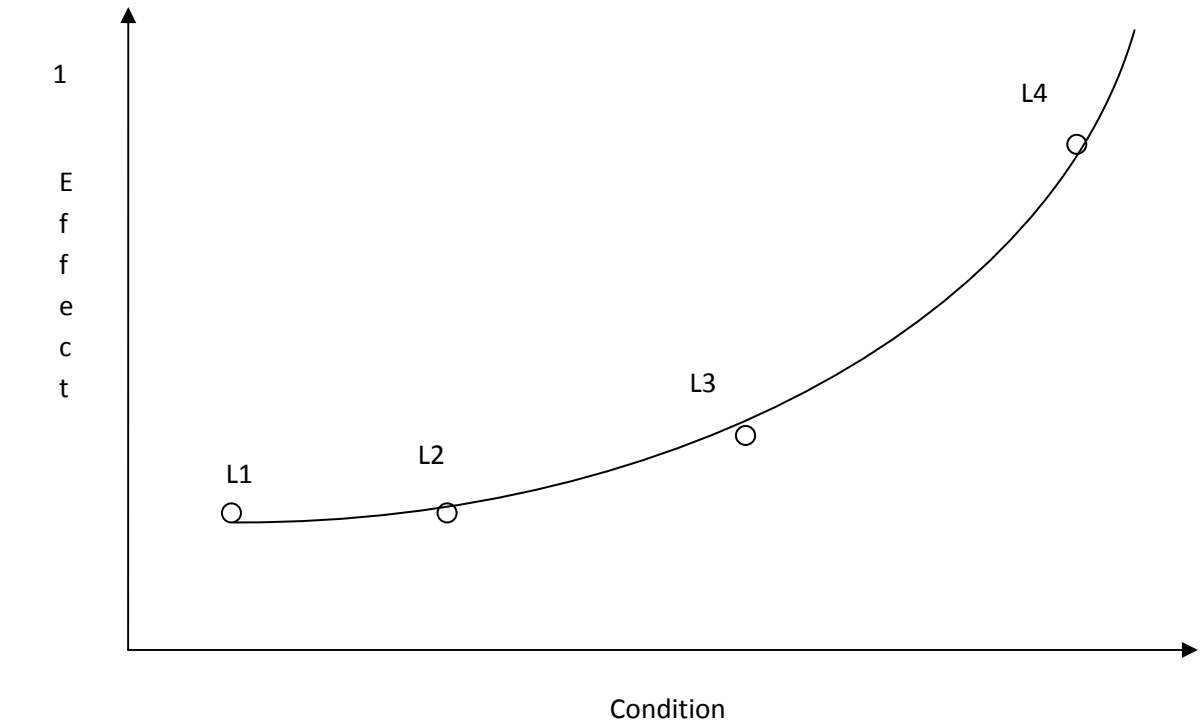

Figure 2. Low vulnerability – high sensitivity