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KNOWLEDGE SCHEMATA OF SOIL SCIENTISTS FOR DEVISING SOIL SAMPLING SCHEMES

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ABSTRACT

Understanding human mental process of interpreting visual scenes through knowledge schemata is important to cartographers since it is essential for designing more effective maps from the user needs perspective. Among the approaches to studying knowledge acquisition described in the literature on cartography we adopted the structures of knowledge (cognition) for the development of this research which was applied to soil survey. The research methodology comprises two steps: identification of which spatial variables are related to scientific definition of soil and, definition of knowledge schemata of soil. Using a questionnaire technique we identified the soil's spatial variables. The questions were about the subjects' professional function, employment context and level of specialized knowledge about soil, and how they use cartographic products for designing soil survey. The first results were achieved from the analysis of a question about their first mental image when they think about soil. The second analyzed question was intended to define which spatial variables are fundamental for characterizing soil. These results were used in the next task which aimed to understand the knowledge schema of the subjects who were asked to answer about 3 related issues: which spatial variables are related to soil definition; what are the attributes of each of those variables; what are the relationships among those spatial variables. The knowledge schema was defined based on 3 types of relationship: soil to variable; variable to variable; and variable to attribute. This result allowed us to understand how the subjects of the experiment use soil attributes and variables in their analysis. For future researches we recommend to replicate this experiment to a larger number of soil scientists and to analyze the results based on a statistical level of significance which would make the proposition of a generalized knowledge schema possible.

BACKGROUND AND OBJECTIVES

Cartography is important either for soils inventory when terrain physical characteristics are analyzed or for drawing a first sketch map of soils units by using thematic maps, such as lithology, geomorphology, climate and terrain slope. The development of computer technology has broadened the set of techniques employed in creating cartographic representations for surveying and mapping soils. There is evidence that the use of these new techniques provides satisfactory results, such as those presented by Rasmasundaram et al. (2005) and Zhu and Chen (2005). However, although the technological development in cartography we still do not know enough about how the processing of information really occurs in the human brain.

Considering that soils scientists use cartographic representations of the main landscape aspects related to soils to take any decision about soils mapping, our research hypothesis is that cartographers, being aware of soils scientists knowledge schemata about soils, can design better maps, either 2D or 3D, for these specialized users. In order to verify this hypothesis the first step of our investigation was to study the human beings process of acquiring spatial knowledge from maps. Therefore, the main objective of the research described in this paper was to draft an initial outline of the general knowledge schemata of soils scientists.

In a systematic approach of soils sampling and description, it is possible to distinguish two phases in which cartography is decisive for soils scientists. The first phase is related to the initial investigation – an inventory stage – when the soils scientist analyzes a series of graphic representation of physical features of the area where the soils survey has been being developed. The second phase refers to preparing a soils map. This research emphasizes the first phase in which the soils scientist uses some representations of the physical characteristics of the region, such as: lithology, geomorphology, climate and slope, in order to present an initial draft of the soils mapping units and to define the data sampling sites.

Among the existing approaches for studying human process of knowledge acquisition we chose the one that is based on understanding the high level processing of information by considering the knowledge structures (cognition) (MacEachren, 1995). Understanding how the processing of information occurs, activated by visual stimuli, is of fundamental importance to the cartographer and to the users of cartographic representations. For the cartographer, understanding the mental processing of information make him/her able to create effective maps since the user acquisition of knowledge is the basis of map design decisions. For the users, the cartographic representations created by the cartographer make the task of acquiring knowledge from maps easier which is a condition for making better decisions in developing their professional tasks.

For Visvalingam (1989) the maps are holistic representations of the spatial reality, being an intellectual abstraction of this reality. Furthermore, the maps can be communicated, modeled and coded, in a way that explores the human capabilities of processing spatial information. In order to create representations that effectively communicate information related to the phenomenon being studied, it is important to understand the process of acquiring knowledge from using maps, that is, it is necessary to try to understand how the spatial cognition process occurs. Cognition includes perception, learning, understanding, thought, memory, reasoning, spatial problem solving and mental images (PETERSON, 1987), to which Montello (2002) adds communication. Cognition comprises a set of perceptive abilities and reasoning capacities of human beings that are responsible for the formation, storage and updating of the structures of knowledge (MACEACHREN, 1995).

Two aspects of knowledge structures are important to cartography: the process of mental categorization and the knowledge schemata. The knowledge schemata are formed by categories and their relationships and it is fundamental for the acquisition of spatial knowledge (MACEACHREN, 1995).

The way human beings mentally categorize determines the elements and the type of relationship that is available to the knowledge schemata. The mental process of categorization allows the creation of spatial representations, since it makes human beings capable of grouping elements, identifying standards and discovering relationships which are fundamental mental tasks for the representation of spatial concepts (MACEACHREN, 1995). Lakoff (1987) claims that a hierarchy exists among categories stored in the human memory. For the author, those categories, when they are combined with the actions we humans can take, are the fastest learned and most used, and they can help us to understand the most complexes phenomena. They are called basic level categories. These basic level categories are the most general, by which a simple mental image can be formed. There are a great number of attributes associated with this kind of category, and these attributes share both the perceptive characteristics and also the functional ones (LAKOFF, 1987).

It is important to consider the characteristics of knowledge in order to conceptualizing knowledge schemata. Following the guideline described by MacEachren (1991), for this research we adopted the spatial knowledge categorization system developed by Golledge and Stimson (1987). This system recognizes three types of spatial knowledge:

- Declarative knowledge: knowledge of the lowest cognitive level, which permits to identify objects that can be directly perceived as places and their attributes;
- Configurational knowledge: knowledge of a higher cognitive level, which involves the understanding of spatial relationships, permits the identification of geographical standards and the development of hypothesis on spatial groupings;
- Procedural knowledge: knowledge of high cognitive level which assists in making decisions about moving around within an environment.

Knowledge schemata are structures that represent and organize concepts in our long-term memory. These structures can be conceived as models containing nodes and linkages between them. The nodes represent categories, or attributes of categories, and the linkages specify the possible relationships that can be maintained between the categories or between the attributes. The knowledge schemata assemble what is known from objects, concepts, relationships, processes in the world and what can be seen on the basis of certain groupings, categorizations and standardizations (MacEachren, 1995).

MacEachren (1995) describes three different knowledge schemata, which can possibly be used by human cognitive processing: the propositional schemata, the image schemata, and the event schemata. The propositional schemata is responsible for interconnecting the sensory input with the representation of the propositional knowledge. This schemata can be considered as the knowledge schemata regarding to objects, concepts and categories. The image schemata provides a format for codifying simultaneously information of vision and language; it is a more fundamental level (basic categories' level) than the propositional schemata (LAKOFF, 1987). Structures that emphasize the time, the sequence and the process constitute the event schemata. The knowledge schemata can be employed one inside another and at all levels of abstraction. No rule exists regarding the employment of knowledge schemata; they are loaded in accordance with the graphic scene visualized (MACEACHREN, 1995).

MacEachren (1995) proposes a general map schemata for understanding maps, which is similar to the general graphic schemata presented by Pinker (1990). The general map schemata is essentially derived from pre-conceptual structures, associated with the basic level concepts and the synesthetic image schemata. These schemata are partially derived from the human physiological characteristics and partially from learning actions required for the adaptation to the physical and social world.

MacEachren (1995) also affirms that in addition to a general map schemata, human beings can make use of a specific map schemata. According to the author, the specific map schemata can be developed by the use of a general map schemata. In this kind of situation the general map schemata is used to recognize that the objects of interest are on the map and, thus, note the characteristics that do not match or are missing in the general schemata. The development of a specific map schemata is a process of modifying, expanding and completing with details the general map schemata, which occur in daily experiences.

APPROACH AND METHODS

The methodology of this research work basically consisted of the characterization of the spatial knowledge of soils concepts of the participants in the experiment. The methodological instrument employed to execute that task was a questionnaire, which was applied to soils Scientists. The questionnaire was constructed with the objective of identifying the principal spatial variables, the attributes and the relationships utilized in soils analyses. The answers from each of the subjects were recorded and subsequently transcribed.

The questionnaire is organized in three main parts. The part 1 questions are written in the table 1. The aim of the questions from one to five was to characterized the experiment subjects. The question six was intended to help us to understand the concept of soils that is stored in the knowledge schemata of the subjects. Finally a list of variables related to the concept of soils was a result of the answers to the question 7.

(1) Name (optional)
(2) What is you education degree?
(3) What is your field of research and teaching?
(4) Which courses are you responsible for?
(5) For how long time do you work at soil science?
(6) What is your first thought (mental image) when you think about soil?
(7) What spatial variables do you consider as essential for the characterization of a soil unit?

Table 1 – The first part of the questionnaire – the subjects' profile

The purpose of the second part of the questionnaire (table 2) was to understand the relationships between: soils variable to other soils variables; soils variable to soils variable attributes; and soils variable to soils concept. The soils variables were listed from the answers of the question 7 above (table 1).

(8) considering the variables listed as the answer to the question 7 above, please fill in the following form:		
spatial variables related to the concept of soil:	the main attributes of these variables:	for each spatial variable you cited in the first colum, to which of those other variables it is related to:

Table 2 – The second part of the questionnaire – the relationships among the variables related to the concept of soils

The third part of the questionnaire, showed in the table 3, was aimed to understand how the soils scientists use cartographic representations in a soils survey. From the answers to the question 9 we tried to know if they use soils maps for acquiring knowledge of other spatial phenomena, and if they do so it would be possible to understand the relationship between their knowledge schemata to other spatial phenomena. Question 10 was intended to know if the experiment subjects use spatial representations of the soils variables to develop their jobs as soils scientist. And from the question 11 we were told by these subjects in which stage of the soils survey the cartographic representations are essential.

(9) Do (or did) you use soil maps or soil suitability maps for the analysis of some other spatial phenomena?
(10) What kind of cartographic products do you use when you develop a soil survey?
(11) For which stages of a soil survey do you use cartographic products?

Table 3 – Third part of the questionnaire – how the spatial representations are used in a soils survey

The selection of the potential subjects for this research was made by searching a Brazilian curricula database which is used by the majority of the Brazilian scientists. Based on this database information we selected forty potential subjects who were asked for participating in this experiment. We received a positive answer from twelve of them who were willing to collaborate in the research. Table 4 illustrates the academic background of these twelve subjects. It is emphasized that all the participants were involved in activities related to soils Science.

Field of research and teaching	Degree	Major of the highest degree
GEOGRAPHY	master	FOREST ENGINEERING
AGRONOMY	Post-doctoral	SOIL SCIENCE
AGRONOMY	doctoral	FOREST ENGINEERING
AGRICULTURE ENGINEERING	doctoral	AGRONOMY
GEOGRAPHY	doctoral	PHYSICAL GEOGRAPHY
GEOLOGY	doctoral	GEOCHEMISTRY AND GEOTECTONICS
AGRONOMY	master	SOIL SCIENCE
GEOGRAPHY	doctoral	PHYSICAL GEOGRAPHY
GEOGRAPHY	doctoral	FOREST ENGINEERING
AGRICULTURE ENGINEERING	doctoral	IRRIGATION AND DRAINAGE
GEOLOGY	doctoral	GEOSCIENCE AND ENVIRONMENT
GEOGRAPHY	doctoral	GEOCHEMISTRY AND GEOTECTONICS

Table 4 – Academic background of the research participants

RESULTS

The first item to be discussed in this paper is related to the first mental image of the subjects when they talk about soils. Of the twelve participants, eight mentioned the soils profile as their initial image. This shows that the majority of them consider the soils profile be the fundamental sample unit for studying soils. In addition, these researchers adopted as the principal image of a body that is continuous in space, a vertical section that restricts their visualization in two dimensions. According to Barros (1985), a soils profile can limit the knowledge about soils because it does not make the representation of the natural structure of this body possible, since its lateral variations are not observed or indicated on it

Two other subjects produced similar answers, as they cited that their first soils image is related to the functions of the soils as a natural resource and producer of food. Of the twelve subjects, two drew attention by their answers: one stressed the distribution and mapping of the soils, and the other a vision of sustenance and system. The conclusion here is that these two subjects have a well developed cognitive schemata because it was possible to discern in their explanations a series of relationships to other spatial phenomena that are important to them. The subject who mentioned system, for example, understood the soils as a dynamic body, with complex relationships to other spatial phenomena, such as the relief, the slope and the geology. The subject who brought up distribution and mapping have a very similar vision, despite the use of different words in explaining the answer for the question. It can be stated that these subjects have knowledge schemata developed to the point of already turning into image schemata. This signifies that for them the concept of soils has already reached a basic mental level of categorization, which permits them to connect talks and images in the identification of standards and relationships. We are not stating that these subjects have a greater knowledge of soils than the others. We are just saying that they responded to the sensory stimuli with more structured ideas. Although this capability can make the comprehension of the concept being analyzed faster it does not guarantee that more knowledge is being acquired.

After the first analysis of the questionnaire we identified which are the principal spatial variables related to the soils concept. Table 5 shows the spatial variables mentioned and their respective frequencies.

VARIABLES	FREQUENCY	VARIABLES	FREQUENCY
soil use and occupation	8	lenght of ramp	1
geology	7	soil color	1
relief	7	soil density	1
hydrography	4	soil grain size distribution	1
climate	3	hypsometry	1
slope	3	orientation	1
geomorphology	3	effective depth of the root system	1
morphology	3	Physical-hydric variables	1

Table 5 – Spatial variables related to the soils concept

It should be stated that the variables of soils use and occupation, geology, relief, hydrography, climate, slope, geomorphology and morphology were the most often quoted. In addition to the direct answers the answers were arranged in groups in order to know when the subjects were referring to the same subjects but by some different names. Furthermore, there were disagreements among the subjects about what is a spatial variable in relation to the soils concept and what is an attribute of the spatial variable. These divergences are not discussed in this paper since it is understood that the contribution of this research resides in the identification of the concepts related to the soils, and not in how they are mentally categorized by each of the subjects.

Based on the variables listed in the table 5, on the conversations to the subjects and on the relationships identified by the subjects between variables and/or between variables and their attributes, it was possible to recommend a soils general knowledge schemata for the subjects who participate in the experiment (Figure 1) (Prado, 2007). The schemata illustrated in Figure 1 is similar to the general graphic schemata proposed by Pinker (1990) and to the general map schemata defended by MacEachren (1995).

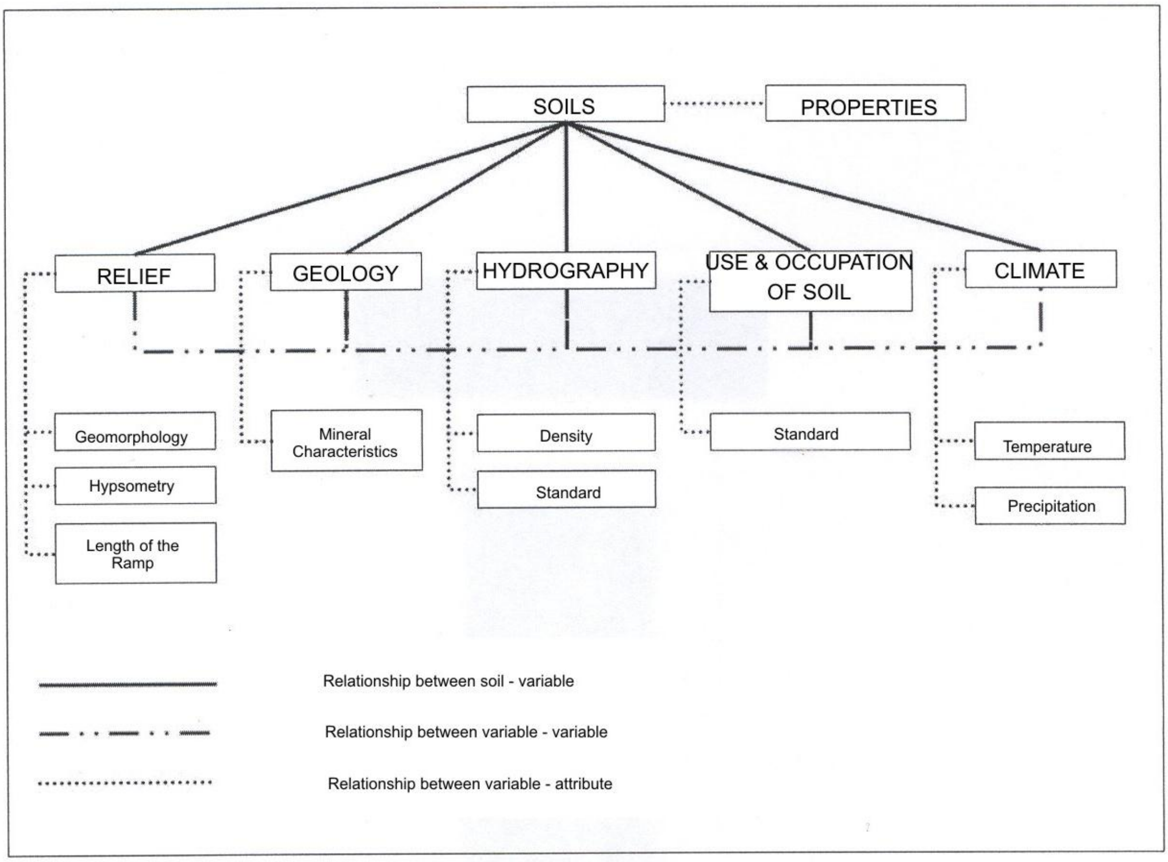

Figure 1 – General knowledge schemata for soils

The identified relationships were categorized and represented in Figure 1. A continuous line illustrates the relationships between the soils and the other variables, since the understanding of the soils was the starting point. With this relationship defined, it was emphasized the order of identification of the remaining relationships. A line represented by dots and dashes illustrates the relationship between the variables cited at low frequency. It is important to notice that every variable is related to some of the others. Dotted lines identify the relationships of the variables with the principal attributes, that is, the most cited attributes. It is emphasized that the term "properties", as identified in Figure 1, refers to the soils properties – physical, chemical or morphological – that are considered to be attributes of the soils.

Figure 1 illustrates a generalized schemata created on the basis of the information provided by the subjects participants in the experiment. Therefore it is not possible to generalize the results to a larger number of people. As discussed in the revision of the literature, each subject develops his knowledge schemata in a different manner. Then individual knowledge schemata depends on the life experiences, cultural influences and thus every soils scientist have unique experiences on interacting to soils concept.

Since the principal concepts of soils were identified, it was investigated how the subjects utilized them in their analyses. The intention here was to verify if they used cartographic representations in making decisions, i.e., to understand to what extent cartographic representations are utilized to feed their respective knowledge schemata related to soils. Therefore, one of the questions addressed to the subjects was: "which cartographic products do you use for developing soils surveys?" Table 6 shows the answers. The most frequently mentioned representations are directly linked to the variables identified by the subjects as being related to the soils concept. They are aerial photographs, satellite images and soils-use maps which are linked to the variable of use and occupation of the soils.

REPRESENTATION	FREQUENCY	REPRESENTATION	FREQUENCY
aerial photographs	6	soils maps	2
geological maps	6	thematic maps	2
topographic charts	6	slope maps	2
geomorphologic maps	4	hypsometric maps	2
satellite images	4	surface formation maps	1
soils use maps	3	drainage maps	1
relief maps	2	maps of physical-hydric variables	1

Table 6 – Cartographic representations used in soils science

CONCLUSIONS AND FUTURE PLANS

The subjects' answers to the questionnaire confirmed the initial thesis which states that the soils scientists use cartographic representations of the principal concepts relating to soils in order to assist them in making decisions.

The experiment made the identification of the subjects' general knowledge schemata related to the planning phase of a soils survey possible. This schemata is applied by the soils scientists during the soils survey phase as the interface between the variations of the phenomenon being studied and its knowledge representation. It should be emphasized that this schemata is applied in many situations, from the visualization of maps and the reading of textbooks to the field work.

It was possible to determine that, during the planning phase, the result of the cognitive effort of the soils scientist culminates in the identifications of the sampling points, sites where profiles will be opened up in the field, and in the delimitation of the initial draft of the soils limits. Nevertheless, in order to acquire knowledge of cartographic representations they must be effective.

For further work we recommend the development of an experiment with a larger number of soils scientists, in order to reach statistical significance, and thus to be able to generalize the results, since it is understood that the conclusions of this paper are only applicable to the group of scientists who participated in the experiment.

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