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VISUALIZATION OF INTEGRATED KNOWLEDGE FOR SUSTAINABLE DEVELOPMENT DECISION MAKING – THE NATURAL RESOURCES OF CANADA EXAMPLE

WIZUALIZACJA ZINTEGROWANEJ WIEDZY W CELU PODEJMOWANIA DECYZJI ZRÓWNOWAŻONEGO ROZWOJU – PRZYKŁAD DEPARTAMENTU ZASOBÓW NATURALNYCH W KANADZIE

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SUMMARY: Visualization refers to visual perception of various types of graphic representation of geospatial information ranging from static to dynamic presentation (cartographic visualization) to exploratory data analysis (scientific visualization). The project entitled *Visualization of Integrated Knowledge for Sustainable Development Decision Making*, recently initiated in Natural Resources Canada, Earth Sciences Sector, focuses primarily on the former: Web-based, interactive, dynamic representation of information, suitable for effective communication of geospatial concepts in support of decision making. The general objective of the visualization project is to explore, develop and implement visualization techniques capable of translating complex scientific information into a form that readily communicates sustainable development forecast scenarios to various user groups, in particular to policy decision makers in the federal government of Canada. The project is carried out in support of the "Sustainable Development through Knowledge Integration" program. The selected applications, to demonstrate knowledge integration issues for sustainable development decision making, are: sustainable use of energy, sustainable management of forests, sustainable management and rehabilitation of mines, and responsiveness to natural hazards. Visualization tools, in particular user-friendly interfaces, can contribute to the increased use of earth sciences information and knowledge and support more effective decision making. The innovative Web-based interactive visualization techniques will facilitate access to information, integration of multi-source data, hypothesis testing, and communication of integrated knowledge.

This paper presents an overview of the Sustainable Development through Knowledge Integration (SDKI) program, and the Visualization of Integrated Knowledge for Sustainable Development Decision Making (SDKI-Vis) project, and discusses issues related to effective and ineffective communication of geo-spatial information in the decision support system developed to facilitate information sharing about the Georgia Basin region of Western Canada (the Georgia Basin Digital Library).

KEYWORDS: visualization, integrated knowledge, interactive Web mapping, sustainable development, decision/policy making

1. NATURAL RESOURCES CANADA'S EARTH SCIENCES SECTOR APPROACH TO SUSTAINABLE DEVELOPMENT

Natural Resources Canada (NRCan) is a science-based department whose mandate is to promote sustainable development and responsible use of Canada's natural resources; develop an understanding of Canada's landmass; collect and disseminate knowledge on sustainable resource development; provide the national framework of reference for spatial positioning; prepare and publish maps; conduct scientific and economic research related to the energy, forestry, mining and metallurgical industries; and establish and operate laboratories for these purposes (Natural Resources Canada, 2002).

The use of geospatial information in science and policy making is increasing and is likely to become more important over the coming decades. In part, access to advanced technologies and an ever increasing amount of geospatial data has supported this evolution. An important step in facilitating the comprehension of large complex volumes of geo-spatial information is the use of map representation and cartographic visualization. Effective visualization is a key to understanding and can facilitate translation of complex concepts and details for informed decision making (Natural Resources Canada, 2001).

2. THE SUSTAINABLE DEVELOPMENT THROUGH KNOWLEDGE INTEGRATION PROGRAM

The Sustainable Development through Knowledge Integration (SDKI) program, was initiated in June 2003. The program focuses largely on a number of issues related to Natural Resources Canada's requirements for sustainable development. It builds on the concept that Earth Sciences Sector's (ESS) geo-spatial information could and should be used to support decision and policy making. The SDKI program will move the Earth Sciences Sector's research, information and knowledge assets into the decision support environments of government, industry and the public. It will develop technology that facilitates integration of ESS information and knowledge assets, will enhance Natural Resources Canada's capacity to disseminate policy pertaining to Canada's mineral, energy and forestry resources and their responsible use (Richardson, 2003).

The program consists of three conceptual levels. The base level starts with data capture and data re-use. The base level consists of CGDI (Canadian Geospatial Data Infrastructure) framework data which provides continuous and integrated geospatial data for Canada from federal, provincial and territorial databases organized based on international standards. The framework data is categorized into layers of geospatial information consisting of Alignment Layers (Geodetic Control Points and Digital Elevation Models), Land Features/Forms Layers (Landsat Imagery, Hydrography, Hysography, Structures, Roads) and Conceptual Layers (International Boundaries, Provincial Boundaries, Toponymy, Parks, Municipal Boundaries). Framework data serves as the foundation for users to integrate and analyze information.

The next level involves integration of appropriate information to interpret aspects of sustainable development (such as geographic, statistical, economic and demographic).

For example, the GBDL (Georgia Basin Digital Library) uses CGDI data from national and provincial sources for the interactive analysis of data (see Figure 1 and 2).

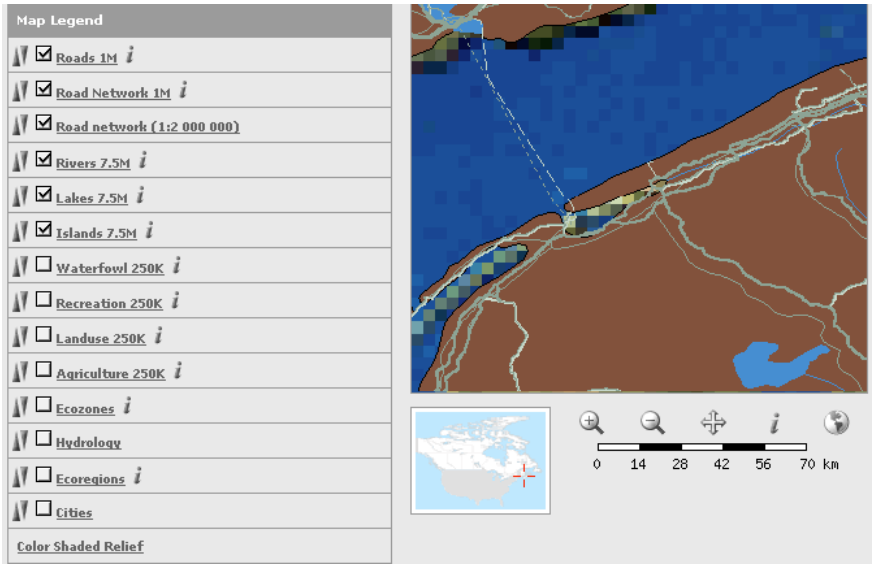

Fig. 1. Example of dynamically generated map interface using the Library Collections module component of the Georgia Basic Digital Library
Rys. 1. Przykład mapy interfejsowej stworzonej dynamicznie przy użyciu elementów z Library Collection, z Biblioteki Cyfrowej Basenu Georgia

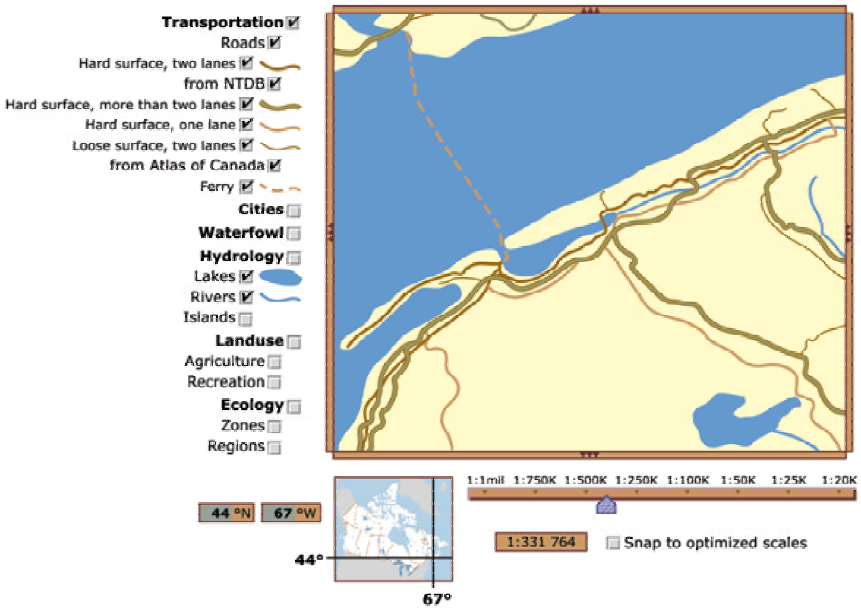

Fig. 2. Example of a prototype for the improved version of the map interface from figure 1
Rys. 2. Przykład prototypu ulepszonej mapy interfejsowej, na podstawie oryginału z rysunku 1

This serves as a base for forecast models of impact of activities and future characterization. Forecast models are based on analyzes of historical data and development indicators to discover trends and to forecast future developments. The top (third) level involves effective communication of Earth Sciences Sector program results (access, visualization and presentation) and input into policy/decision making. The SDKI Visualization (SDKI-Vis) project is part of the third level.

The Sustainable Development through Knowledge Integration program comprises several theme based application projects and two system and methods development projects. The theme projects are: Transport-Related Energy Sustainability in Canadian Urban Areas, Sustainable Management and Rehabilitation of Mine Sites for Decision Support, Forestland Disturbances Monitoring, and Mapping for Sustainable Development Planning and Reporting. The systems and methods development projects are: the PATHWAYS-Decision Support System for Sustainable Development and Visualization of Integrated Knowledge for Sustainable Development Decision Making (SDKI-Vis). This paper focuses primarily on the visualization project as applied to a selected module of PATHWAYS project.

3. VISUALIZATION OF INTEGRATED KNOWLEDGE FOR SUSTAINABLE DEVELOPMENT DECISION MAKING (SDKI-VIS)

The SDKI-Vis project focuses on removing barriers to the effective communication of geospatial information to policy and decision makers. The project addresses the translation of quantitative science output into qualitative presentation – thereby demonstrating the results of modeling undertaken within the SDKI theme projects such as urban analysis, forest disturbances, mines, water and hazards. Forecasts resulting from SDKI themes will be re-presented using methods such as dynamic visualization or 3D interactive terrain representation.

In consultation with the SDKI application project leaders, the project will identify policy/decision makers' requirements for geospatial information visualization related to the sustainable development of natural resources. Further, it will identify, assess and publish a suite of advanced Web-based visualization techniques. More generic visualization methods could then be applied to other programs dealing with integrated knowledge based on geospatial data and information. The project also involves development of a long-term strategy for visualization primarily applied to the SDKI program, with potential links to other ESS programs such as Northern Development, Climate Change, and others.

Before geospatial visualization is discussed, there must be an understanding of how the term *visualization* is used in this paper. Visualization refers to a process of gaining fresh understanding of previously opaque data, typically facilitated by the graphic display of information through an interactive (preferably map) interface. Visualization is an individual and personal activity. The requirements of the moment meet the user's personal history and needs to create unique curiosities that drive their exploration of the information. This insinuated exploration results in the user seeing the information in a new and useful ways.

3.1. Geospatial Visualization – The Cartographic Perspective

Geospatial visualization has emerged as a tool for searching through huge volumes of data, communicating complex patterns, providing a formal framework for data presentation and exploratory analysis of data (Gahegan, 2000). It combines the power of multimedia dynamic representation of spatial information with interactive engagement of users (experts and non-experts) to perform exploratory analysis. Geospatial information relevant for sustainable development often tends to be heterogeneous, complex, not directly comparable and correlated in ways that may not be apparent without the use of visualization techniques. Visualization is important not only in the development of GIS generally, but also as a tool to improve reliability of multiple sustainable development scenarios, and thus decision support, as well as to improve the capacity of non-experts to take advantage of the information presented.

The SDKI-Vis project looks at the cartographic and graphic representation of data and information in the Web-based visualization environment. Particular attention is paid to communication tools Visualization in the SDKI-Vis project, is less concerned with a representation created by an expert, but is more concerned with the exploration by an individual. In this context, cartographic communication as a means of visualizing is considered critical for effective use of geospatial tools and methods.

Based on preliminary research, a number of issues in the cartographic and graphic communication of geospatial visualization can be identified. One of the most fundamental issues involves the suitability of the method used to represent data since technology offers a variety of choices to represent data, i.e., graphs, charts, tables, maps, 3D representation and animation, and it is crucial to select the appropriate method. For example, cartographers warn against using choropleth maps that distribute a risk evenly over a surface when in fact the risk is not homogenous to such an extreme degree that it follows the choropleth boundaries. Another issue is the use of visual variables, namely the hue, size, shape, value, texture and orientation of data symbolized (Bertin, 1983). Because Web-based visualization is technologically sophisticated, it is no longer limited to 2D static maps but includes dynamic and 3D representations. In this case the visual variables described by Bertin are further extended to encompass 3D dynamic representation and VRML (Virtual Reality Modeling), which are dynamically linked with databases and various (mapping) servers worldwide. Once the data is represented, the means of interaction must be considered to allow the user to manipulate variables to create different scenarios. The key to effective data exploration and analysis is the means of interacting with data through functional and user friendly interfaces.

3.2. Challenges of Web-Based Visualization

The SDKI-Vis project will make various information representation methods available for comparison, interaction and compatibility within a geographic context. Various methods that allow the user to manipulate the data display to explore alternate scenarios and consider other outcomes as individually determined will be explored. This will foster in-the-moment visualization so that the user can produce a situated, self-

determined understanding of the data. Further, it will allow the user to be better prepared to propose ways to promote sustainability in future development decisions.

When the user is freed from the operation of the system (sub-directories, spread sheets, windows to open and close), exploring the information becomes the focus of the work. This can best be achieved through merging data queries, data manipulation and data display. The interface device/data display/data query process should be highly intuitive. Transparency is key, as is a feeling of weightlessness in the operation of the interface, achieving a sense of play. Manipulations need to seem like natural actions, and the subsequent reactions need to be apparent. An excellent example of touching the information can be found in the Star Tree search tool (inxight.com). The SDKI-Vis project would like to adopt this notion of contact with the data as the directional means that allows users to see the information in ways that are useful to their particular situation.

A map interface must be responsive in a similar way. As much as possible, the map must serve as the means by which the user explores the information and examines alternate scenarios. Graphic scales must be useful devices for controlling the scale of the map display; the legend must have clear, thoughtful entries that serve as logical and transparent controls of the map content; and navigation must happen through manipulating the map rather than an alternate device, which is separate from the display (see Figure 1).

When the boundary of information display and the means of information retrieval become more and more indistinct, the user can more easily enter the information. Interface metaphors become redundant as the need to construct a user illusion dissolves. It is at this point that the interface design begins to fully engage the Web medium.

3.3. The PATHWAYS Application Project

PATHWAYS is a an ontology-based knowledge integration and Decision Support System (DSS) that will translate earth science information into a form that is compatible with emerging sustainability modeling, planning and decision support frameworks. The system will provide a framework for integrating information and knowledge outputs of complimentary Earth Sciences Sector programs, and will be developed using standards-based Web services technologies, emerging Canadian (Canadian Geospatial Data Infrastructure - CGDI), and international (Open GIS Consortium - OGC) standards for information and system interoperability (Brodaric, 2003).

At present, the SDKI-Vis project is exploring the possible enhancement of visualization components of the PATHWAYS project. The focus is on the Georgia Basin Digital Library.

3.4. The Georgia Basin Digital Library (GBDL)

The library is developed for members of the local community as well as experts interested in issues of sustainable development. The GBDL is composed of the following modules: News & Information, Local Stories, Ideas & Perspectives, Library Collections, and Future Scenarios. The two GBDL modules that display interactive Web maps are the

Local Stories and Library Collections modules. At present, the SDKI-Vis project is working on the evaluation and improvements to the Library Collections module.

The Local Stories module enables online community knowledge development by providing map based tools for exploring and creating user driven multimedia content and is based on established community mapping methodologies developed as a part of the Green Map System initiative (Brawer, 1995). Users can add icons on a base map to denote areas of ecological and cultural interest. Each icon added by a user can be linked to user-created narrative, image, sound and video content. This module empowers users to provide local content and share their collective knowledge of the region. The association created between location and common experience using multimedia content raises the communication level and gratification in the exploratory experience through integrated knowledge based on geospatial data and information.

The Library Collections module uses Open GIS Consortium technologies in a distributed environment to permit users to search metadata registries of the Canadian Geospatial Data Infrastructure and visualize spatial data hosted by a wide-range of spatial data warehouses. Layers of raster and vector geospatial data can be selected and combined for dynamic Web map creation. Rudimentary functionality is available for zooming, panning, and modifying the order of layer stacking and displaying a locator/overview map. Selection of symbols and colours cannot be modified by users. Raw attribute data of an individual map layer can be queried although the results are not interpreted for users.

The map based, layer selection module of the GBDL Library Collections offers the user many map layers that can be turned on and viewed together, thus facilitating integration of information, which is crucial for informed decision making. The capability to create by users maps, composed from diverse layers, is a basic function for comparison and visual correlation of information. This open invitation to explore geo-referenced data from many dispersed databases can be a meaningful and powerful way to foster visualization. But an invitation for unfettered browsing must be offered in a considered and well-structured interface in order for the user's exploration to satisfy curiosity rather than cause frustration. The work involving the Georgia Basin Digital Library will propose improvements to encourage browsing of the information, and to provide greater assurance that a user's explorations will be satisfying. The aim is to align the GBDL to the strategy of weightless, intuitive operation. The improved interface will be incorporated into the QUEST decision support tool of the Future Scenarios module of the GBDL.

One example of a map interface from the Library Collections module of the GBDL, which the SDKI-Vis team will attempt to improve, is shown in Figure 1. While it is beneficial that the legend serve as the layers' on/off controls, this legend provides only the name of the symbol, while it also needs to reflect the symbol as it appears on the map (see Figure 2 for proposed modifications). The map navigation controls will be moved to the map, letting the user push and pull at the map image itself. Other icons need to be re-ordered to make better use of screen space and to create relationships between the devices that control the display and the map itself.

The project team would like to produce containments of the various complexities and the most expert levels of information available in this map construction module.

The most useful and most basic functions need to be placed forward in the hierarchical design of the interface structure. As search options and tangential information become less relevant they will be made available at lower levels of the interface. This unfolding of functionality provides an elegant means to manage complexity, streamline the interface and make it useful to the widest audience.

The SDKI-Vis team feels that high cartographic design standards should be applied to the images produced from a user's explorations. Clarity, encapsulation, figure/ground relationships, good typography, flow, order, and colour balance must all be present. The same high standards must be applied to all forms of graphic communication. To allow these standards to drop will hamper the visualization process.

4. CONCLUSION

The Internet provides ever increasing opportunities for accessing geospatial information. However, clear representation of geospatial information that can be readily used by decision makers still poses many challenges. The SDKI-Vis project is designed to explore and address many of these challenges, in particular, the translation of complex results obtained from forecasting models into simpler forms that can be readily comprehended by decision makers. The project is still in a very early stage of development and only preliminary results have been obtained. The general conclusion is that the decision making process is moving towards more inclusive consultation prior to taking an ultimate decision concerning the various aspects of sustainable development (Jankowski and Nyerges, 2001). Sustainable development is a general concern of society and the responsibility of all and can be accomplished only with increasing knowledge and participation of all citizens (National Round Table on Environment and Economy, 1991). The consultation process must, however, be based on the individual comprehension of information through individual visualization process. The new technologies, in particular, Web-based technologies, will facilitate both learning and participation of all groups within society.

The issues facing the integration of knowledge are technical (such as data and systems interoperability) but also primarily scientific, namely the clear communication of scientific results in the form of well designed graphics suitable for informed decision making. The results obtained so far have resolved some main issues, such as the overcrowding of images, lack of cartographic design principles, or even lack of awareness of the need to apply them. The greatest challenge is the articulation of user needs, since the policy and decision makers this project caters to are often not aware of the existence and importance of geospatial information, or, due to the complexity of the systems.

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S t r e s z c z e n i e

STRESZCZENIE: Wizualizacja to wizualna percepcja różnych typów geoprzestrzennych informacji od statycznych do dynamicznych prezentacji (wizualizacja kartograficzna) do eksploratywnej analizy danych (wizualizacja naukowa). Niedawno rozpoczęty w Instytucie Nauk o Ziemi, Ministerstwa Zasobów Naturalnych Kanady, projekt "wizualizacja zintegrowanej wiedzy w celu podejmowania decyzji zgodnie z zasadami zrównoważonego rozwoju" przede wszystkim zwraca uwagę na interaktywne, dynamiczne przedstawianie danych w oparciu o siec internetu odpowiedniej dla efektywnej komunikacji danych przestrzennych w celu podejmowania decyzji. Głównym celem projektu wizualizacji jest zbadanie, zastosowanie, udoskonalenie lub skonstruowanie nowych technik wizualizacyjnych, które byłyby w stanie przekazywać kompleksowa wiedze naukowa, w formie odpowiedniej do przedstawienia scenariuszy rozwoju zrównoważonego, dla różnych grup użytkowników, szczególnie decydentów z rządu federalnego Kanady. Projekt jest prowadzony w ramach programu "zrównoważony rozwój w oparciu o integracje wiedzy". Wybrane przykłady zastosowań demonstrujące podejmowanie decyzji

w oparciu o zintegrowana wiedze w celu zapewnienia zrównoważonego rozwoju to: wykorzystanie energii, zarządzanie terenami zalesionymi; rehabilitacja kopalń i zarządzenie górnictwem zgodnie, z zasadami rozwoju zrównoważonego i zapobieganie zagrożeniom naturalnym. Narzędzia wizualizacyjne, a w szczególności łatwa dla użytkownika "nawigacja" (interfejsy), w znacznym stopniu przyczyniają się do efektywnego, do podejmowania decyzji wykorzystania wiedzy i informacji z zakresu nauk o ziemi. Nowoczesne interaktywne techniki wizualizacji, oparte o sieci Internetu) ułatwiają dostęp do informacji, a także integracje danych pochodzących z różnych źródeł, testowanie hipotez i udostępnianie zintegrowanej wiedzy.

Niniejsza publikacja zawiera opis programu "zrównoważony rozwój w oparciu o integracje wiedzy", jak również projektu "wizualizacja zintegrowanej wiedzy w celu podejmowania decyzji zgodnie z zasadami zrównoważonego rozwoju". Publikacja ta wprowadza również dyskusje problemów związanych z prawidłowym i nieprawidłowym przekazem informacji przestrzennej w systemach do podejmowania decyzji stwarzanych dla ułatwienia dostępu i wymiany informacji na przykładzie systemu informacji o Basenie Georgii w zachodniej części Kanady (Biblioteka Cyfrowa Basenu Georgii).

SŁOWA KLUCZOWE: wizualizacja, wiedza zintegrowana, interaktywne kartowanie na sieci internetu, zrównoważony rozwój, podejmowanie decyzji i wprowadzanie ustaw

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