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Representation of Landscape Properties and Processes across Scales: Developing Methods and Tools to Facilitate the Interdisciplinary Communication in Extreme Event Analysis and Management

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1. AFFILIATION AND PROFESSIONAL DEVELOPMENT

Chris S. Renschler is an Assistant Professor at the Department of Geography and Research Scientist at the National Center for Geographic Information and Analysis (NCGIA) at the University at Buffalo - The State University of New York, Buffalo, New York. Dr. Renschler is an Environmental System Scientist/Geoecologist by training and received his Ph.D. in Geography in 2000 from the Faculty of Natural Sciences and Mathematics at the University of Bonn, Germany. Prior to his current position, he was a visiting scientist and post-doctoral researcher at the U.S. Department of Agriculture's National Soil Erosion Research Laboratory, the Department of Agricultural and Biological Engineering and the Department of Earth and Atmospheric Sciences at Purdue University, West Lafayette, Indiana. His research focuses on the representation of environmental properties and processes in the digital domain and their transformation across scales for geo-spatial data processing. His data transformation and scaling theories have been implemented in several research projects for developing valid GIScience modeling tools to support timely and effective decision-making in natural resources and natural hazard management.

So far Dr. Renschler secured more than $500,000 in competitive extramural and intramural research grants to support interdisciplinary research projects. Over the past 10 years, he has presented his research in more than 15 invited lectures, 14 professional workshops, and at more than 50 international and national conferences. In addition to the 10 peer-reviewed proceeding papers and 7 refereed book chapters, he has published 12 peer-reviewed articles in highly ranked interdisciplinary and specialty journals in the areas of Geosciences and GIScience. His interest in developing methods and tools to facilitate and to promote communication among interdisciplinary research activities in GIScience and Environmental Modeling resulted in the following: (a) chairing the Organizing Committee for the 36th Binghamton Geomorphology Symposium on "Geomorphology and Ecosystems" (2005), (b) an invitation to become a member in one of ten Strategic Strength Planning Committees of the University at Buffalo focusing on "Extreme Events: Mitigation and Response" (2005), (c) an invitation to serve on a national expert panel on "Planning for Extremes at Watershed/Regional Scales in the Great Lakes Region" for the Soil and Water Conservation Society in the US and Canada (2006), and (d) presenting to congressional staff members at the UCGIS Winter Meeting 2006 on "Geospatial Information Science and Technology: An Integrating Force in Disaster Preparedness, Mitigation, and Recovery" .

2. CONTRIBUTIONS TO AND EXPECTATION OF THE WORKSHOP

Renschler will contribute with his research expertise in analyzing the challenges, solutions, and uncertainties in transforming geographic information across spatiotemporal scales and disciplinary boundaries. His research offers solutions in integrated assessment approaches that allow collaborators to communicate effectively and efficiently about spatiotemporal landscape properties and processes and their extremes in an accurate and appropriate manner. These truly integrated assessment approaches combine a universal spatiotemporal scaling theory, a collaborative research and teaching platform with meta-data information management, and various geo-spatial interface approaches that assist model developers to design and users to utilize the next generation of interdisciplinary, integrated environmental assessment models. Such models are based on a holistic perspective of environmental systems and information systems integrating monitoring and modeling. Renschler expects that the workshop participation will allow him and other participants to exchange ideas and further develop existing research projects and coordinate future grant proposal submissions with other workshop participants. The goal is to publish a book on a future research and development agenda and an edited book to address broader issues and research challenges. This is a great opportunity to collectively publish state-of-the-art ideas and concepts on the workshops topical areas.

3. VISION, RESEARCH SYNOPSIS, AND RESEARCH LEADERSHIP

Renschler believes that practical decision-making of environmental managers assessing the impact of natural variability and the impact of human activities often involves using environmental process models linked with Geographic Information Systems (GIS). Optimum use of these techniques for such decision-support requires careful and coordinated consideration of how the natural spatiotemporal processes, the gathered observations, the modeling algorithms and related uncertainties are represented in data and how simulation models are used. To avoid wasting resources and time on inappropriate data collection, improper model use, and resulting poor decision-making, there is a pressing need for a scientific and functional framework within which to examine implementation and use of geo-spatial assessment tools (Renschler, 2006; Namikawa and Renschler, 2003). To be useful for researchers, engineers, and decision-makers, integrated environmental system simulation approaches must consider the spatial and temporal variability in natural processes and utilize to the maximum extent possible the latest data sources that are available at variable scales. There are certain limitations in the ontology of classification schemes (Sorokine et al., In Press) and data formats that are used in Geographical Information Science (GIScience) as well as in modeling tools to represent environmental properties and processes appropriately and accurately (Renschler and Harbor, 2002; see also Fig 1). With the latest technology in data gathering methods, we achieve an increasing amount of detail in representing environmental properties at a particular scale, but are still unable to communicate effectively among participating disciplines using this detailed information to predict landscape processes at various spatial and temporal scales. These issues become apparent when we try to develop decision support tools to predict overland flow generation, soil erosion and deposition on hillslopes and channels in small watersheds (Renschler, 2003) or assess the risks of geohazards in volcanic landscapes (Renschler 2005).

3.1 THE SCALING THEORY

In using process models for decision-making, the primary focus is basically on the decision-maker's scales of interest (assessment results), availability of data sets that might support appropriate model applications (assessment base), and the choice of a model that is adequate for the decision-making goals (assessment core). These three concurrent initial steps define the questions to be answered as well as the models and data sources to be used. In general, however, it is potential users' scales of interest, and scales of readily available data that should drive model design or selection, as opposed to using or designing the most sophisticated process model as the starting point and then determining data needs and result scales (Renschler, 2003). Because integrated geo-spatial assessment requires careful consideration of all the steps in utilizing data, modeling and decision-making formats, each step in the scaling sequence must be assessed in terms of how data is being *scaled*. Scaling is referred to here as the transformation of information from one spatial/temporal scale to another (e.g. an interpolation, aggregation, disaggregation, etc.). Usually data transformation in the digital domain occurs in the following sequence (see Fig. 2): (1) Process Scale, (2) Measurement Scale, (3) Database Scale, (4) Modeling Scale, (5) Prediction Scale, (6) Assessment Scale, and again (1) Process/Validation Scale.

The two basic scaling steps at the *Process Scale* (Fig. 2; Step 1) represent the transformation of a true pattern of a natural process to measured data, and all other steps deal with digital information handling. The main reason for assessing data transformation results at each step throughout the sequence by considering each to be simultaneously a *Validation Scale* is to ensure that the results of each step maintains those characteristics of the original data that are critical in controlling the final decision-making. For example, if aggregated data lead to results that vary enough from those produced using original data that it will affect the identified management decision, it is critical for a model developer to find out about it for recommendation purposes, a (geo-spatial algorithm) developer to report about it in an attached metadata file, and a user to get to know about it for instance during the data transformation (scaling) takes place.

Similarly, if the final management decision at the *Validation/Process Scale* is not sensitive to the use of readily available aggregated data, there is no need to spend time and resources on collecting more detailed data. Thus, an additional benefit is that this assessment allows identification of areas where less sophisticated approaches or less restrictive data requirements might be used without compromising the final outcome of the decision-making process. However, such an assessment might also identify steps where data inaccuracy or transformations introduce error or uncertainty that is beyond tolerable levels in terms of the impact on final decision making. Explicit recognition of this helps reduce the risk of poor decision-making. It is important to recognize that the scaling steps can also be used as a framework for building a sequence of data transformations focused on providing results that are both adequate and accurate enough for the decision-maker's scales of interest. Enabling the user to set certain thresholds for acceptance along this sequence of data transformation creates awareness and a level of user confidence that the interface handles data and model in an appropriate way.

3.2 EFFECTIVE DATA MANAGEMENT TOOLS

As a result of successful interdisciplinary, collaborative research, the Geo-spatial Project Management Tool (GeoProMT) was developed. GeoProMT is an internet-based interface for the management of shared geo-spatial and multi-temporal information such as measurements, remotely sensed images, and other GIS data (see also Figure 1). Integral to the GeoProMT framework is role-based access control (RBAC), where data access permissions and data users are associated with appropriate roles, enabling efficient collaboration among participants of large interdisciplinary geo-spatial projects. The mission of collaborative investigators was the development and integration of user-friendly GIScience and environmental modeling tools using readily available data sets to support a rapid, practical and effective decision-making in integrated environmental and disaster management (Renschler et al., 2006).

3.3 GEOSPATIAL MODEL INTERFACES FOR PROCESS MODELS

Traditional process models, such as the Water Erosion Prediction Project (WEPP) were not typically developed with a flexible Graphical User Interface (GUI) for applications across a wide range of spatial and temporal scales, utilizing readily available geo-spatial data of highly variable precision and accuracy, and communicating with a diverse spectrum of users with different levels of expertise. As the development of the Geo-spatial interface for WEPP (GeoWEPP) (Renschler, 2003) demonstrates, that also the GUI plays a key role in facilitating effective communication between the tool developer and user about data and model scales. The GeoWEPP approach illustrates, that it is critical to develop a scientific and functional framework for the design, implementation and use of such geo-spatial model assessment tools. The way GeoWEPP was developed and implemented using the previously described scaling theory led to a practical approach for designing geo-spatial interfaces for process models. GeoWEPP accounts for fundamental water erosion processes, model and users needs, but most important it also matches realistic data availability and environmental settings by enabling even non-GIS-literate users to quickly assemble the available geo-spatial data to start soil and water conservation planning. In general, it is the potential users' spatial and temporal scales of interest, and scales of readily available data that should drive model design or selection, as opposed to using or designing the most sophisticated process model as the starting point and then determining data needs and result scales.

3.4 CONCLUDING REMARKS

The integrated assessment of the spatiotemporal variability of landscape properties and processes combines a scaling theory, geo-spatial project management, and process modeling which allows researchers to communicate effectively across disciplinary boundaries. The successful implementation of GeoWEPP for assessing the impacts of soil and water conservation Best Management Practices (BMPs) in small watersheds (Renschler and Lee, 2005) and the multi-temporal and spatially-distributed validation approach (Renschler, 2006) shows the usefulness of Renschler's integrated assessment and management approach.

4. REFERENCES

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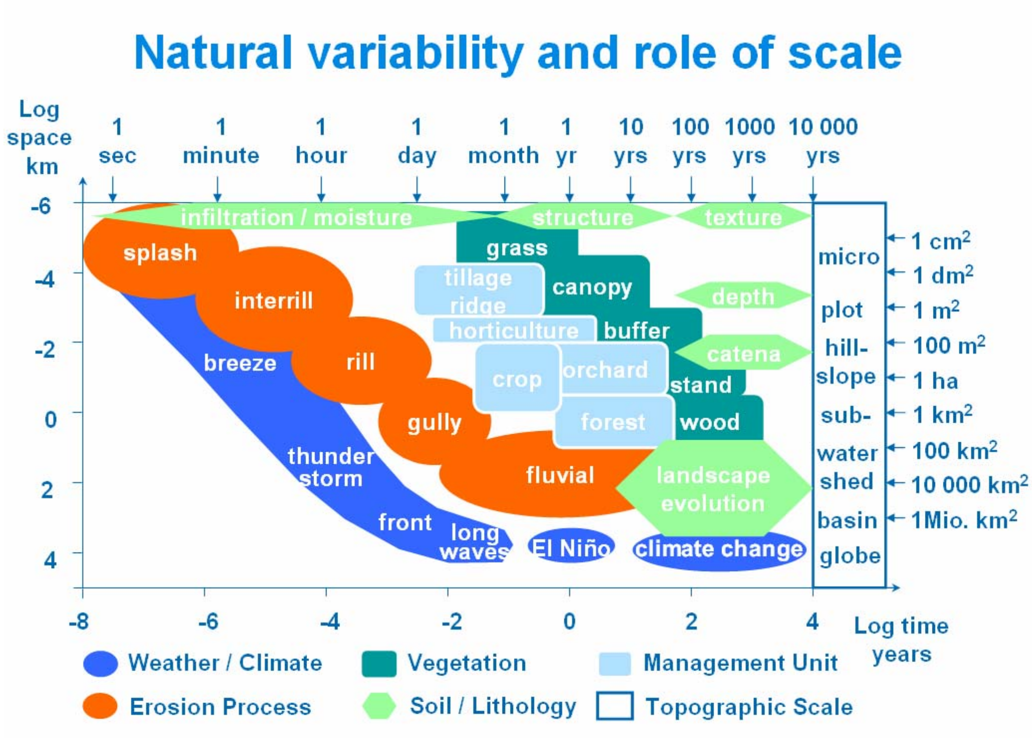

Figure 1. Spatiotemporal extent of atmospheric, topographic, soil, and vegetation phenomenon important for dominant soil erosion processes. The management units indicate extent of human interest and impact often influencing the behavior of natural processes and extreme events (after Renschler and Harbor, 2002).

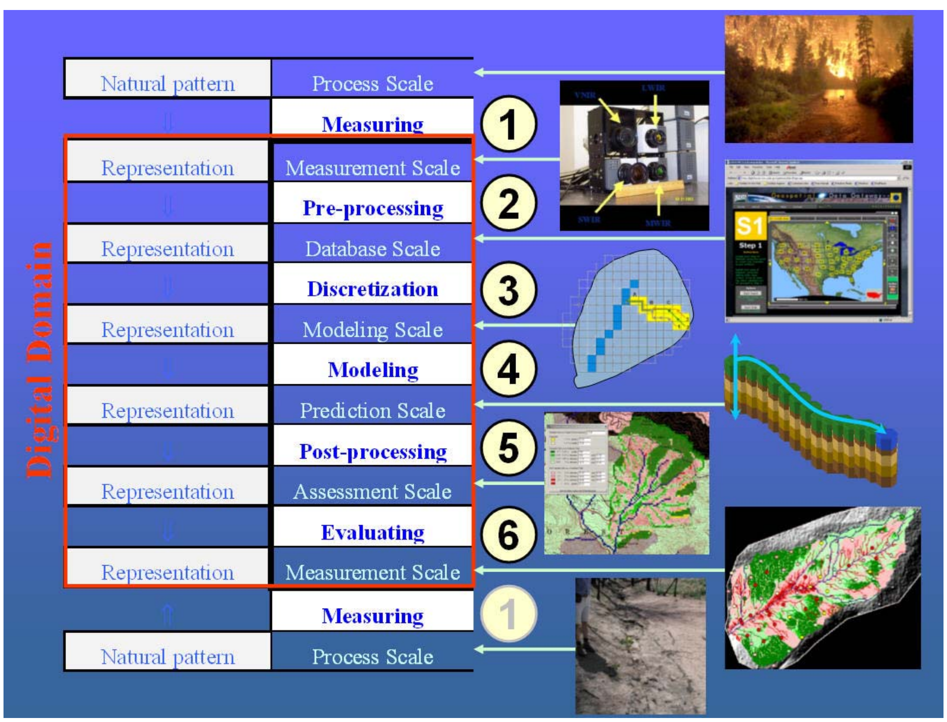

Figure 2. Scaling theory describing and documenting the transformation of information of spatiotemporal landscape properties and processes across scales (Renschler et al., 2006).