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Content

About ISEM

The International Society for Ecological Modelling (ISEM) promotes the international exchange of ideas, scientific results, and general knowledge in the area of the application of systems analysis and simulation in ecology and natural resource management. The Society was formed in Denmark in 1975, and today has chapters in Germany, Italy, Japan, and North America. ISEM Sponsors conferences, symposia, and workshops that promote the systems philosophy in ecological research and teaching, and in the management of natural resources. The Society publishes the newsletter ECOMOD, and its members frequently contribute articles to the official scientific journal of the Society, *Ecological Modelling*.

Perspectives

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A Model of Increased Accuracy for Predicting Radionuclides Transport in the Kiev Reservoir

Abstract

Predicting the transport of radionuclides in the Dniper River reservoir in Kiev remains important because ^{90}Sr contamination continues to wash out into the Dniper from territories surrounding the Chernobyl nuclear station. In this article I analyze a box model with complete mixing (WATOX) on the distribution of ^{90}Sr in the Kiev reservoir after the Chernobyl accident and define the major factors that influence transport of radionuclides. I also describe a new box model of incomplete mixing with a time-lag parameter (UNDBE). UNDBE increases accuracy of the prediction of pollutant concentration in the outflow of the reservoir, particularly for short-term predictions. UNDBE is not much more complex than WATOX. One can calibrate UNDBE for different reservoirs and pollutants or can use the model for various prognostic tasks, such as optimizing water usage.

Key words: radionuclide transport, ^{137}Cs, ^{90}Sr, watershed, box model.

1. INTRODUCTION

^{137}Cs and ^{90}Sr heavily contaminates the floodplain territories near Chernobyl Nuclear Power Plant (ChNPP) and surrounding watersheds. The major part of the radionuclide wash-off is found in the watershed of the Pripyat River, the right-hand tributary of the Dnieper river. The highest level of radioactivity in the water of the Pripyat River was observed during the initial period after the accident. Radionuclide contents in the river flow decreased from 1986 to 1998. The largest part of the annual runoff flows through the reservoirs during the spring flood, from March until June. Contaminated areas also exist in the upper Dnieper watershed on Russian and Belorussian territories. Radionuclides washed-off from watersheds are transported to the Black Sea through a system of six reservoirs located along the Dnieper River. The level of ^{137}Cs concentration in the Dnieper reservoirs has dropped since 1986 (and it is now comparable to the pre-accident levels) as a result of the decrease in ^{137}Cs washout rate. Unfortunately, the ^{90}Sr wash-off rate did not decrease similarly. Therefore ^{90}Sr contamination remains the most significant problem during high spring floods in the Pripyat River. Even 14 years after the accident the contamination problem remains critically important because Dnieper water is consumed by more than 8.1 million people. The reservoirs are also used for commercial fishing and more than 1.8 million hectares in Ukraine are irrigated by the Dnieper river.

There are many approaches to model contamination transport in surface waters (IAEA 1985). In fact, several types of models were developed. As it was urgent to increase the predictability of models for post-Chernobyl era, models for pollutant transport (especially radionuclides) had to be improved. From another side it is possible to compare mathematical models and field measures. A set of models of different levels of complexity (from three-dimensional to box) was developed at the Kiev Cybernetics Center to simulate radionuclide transport in the Dnieper reservoirs (Morozov et al. 1996). The simplest of them is WATOX, a box (complete mixing) model, for which variables are averaged over the volume of the compartment representing either the whole reservoir or its major section. Such models are less sensitive to the quality of initial data than existing more complex 1-, 2-, or 3-dimensional models. The use of the latter models imposes fundamental constraints on the possibility of obtaining an accurate prediction because substantial accurate initial and boundary data are needed, and much computer time is spent for calculation. Thus, the solution of parameters identification problems remains difficult. This paper presents a new box model, UNDBE, which has the same simplicity as WATOX. However, its predictive capacities were improved.

2. POSSIBILITIES OF THE BOX MODEL

Box model can be derived from three dimensional equations by averaging over a compartment area. The model assumes that contaminated water discharges into the compartment instantaneously and completely and mixes evenly with the compartment water. Therefore, the concentration of contaminants in the outflow is the same as that in the compartment. Linear relationships are used to model the dependence of contaminants on factor K_s for contaminants in suspended sediments and K_d for contaminants in bed deposition. The resulting set of the ordinary differential equations (Zheleznyak et al. 1992) describes the dynamics of the water volume in a box and the compartmentally averaged value of the suspended sediment concentration. The concentrations of the radionuclide in solution and in suspended sediments and leached to the bottom are predicted.

The water balance equation for the set of consecutive compartments is given by:

$$(1)\quad \frac{dV_i}{dt} = Q_{i-1} - Q_i + R_i + \sum_{j=m}^{n} Q_j^t - Q_i^w$$

where V_i is the volume of compartment i, Q_{i-1} the amount of water discharged from the previous compartment, Q_i the amount of water discharged into the next compartment, R_i the difference between precipitation and evaporation rate, Q_j^t the amount of water discharged from tributaries of the compartment, and Q_i^w the water consumption rate.

The mass of contaminated bed deposition is assumed to be constant and is described as:

$$(2)\quad M_i^b = \rho_s (1-\varepsilon) Z_* F_i$$

where ρ_s is deposition density, ε porosity, Z_* the effective thickness of the contaminated sediment, and F_i the area of free surface. The suspended sediment concentration equation averaged over the compartment volume in relation with boundary sources is written as follows:

$$(3)\quad \frac{dS_i}{dt} = \frac{1}{V_i}\left(Q_{i-1}S_{i-1} - Q_* S_i + q_i^b - q_i^s + R_i^h + \sum_{j=1}^{m} Q_j^t S_j^t\right)$$

where

$$(4)\quad Q_* = Q_{i-1} + R_i + \sum_{j=1}^{m} Q_j^t$$

R_i^h is the sediment flux into the compartment due to coastal erosion, S_i and S_{i-1} are the sediment concentrations in the outflow (i) and (i-1) compartments, respectively; S_j^t is the sediment concentration in tributaries of the compartment; q_i^b and q_i^s are compartmentally integrated rates of resuspension and sedimentation and are calculated from the equilibrium suspended sediment concentration (transport capacity of the flow) S_*:

$$(5)\quad q_i^S = \begin{cases} F_i w_0 (S_0 - S_*), & S_0 > S_* \\ 0, & S_0 < S_* \end{cases}$$

$$(6)\quad q_i^b = \begin{cases} 0, & S_0 > S_* \\ BF_i w_0 (S_* - S_0), & S_0 < S_* \end{cases}$$

where w_0 is fall velocity (function of the suspended sediment grain diameter D), S_0 the effective concentration of sediments in the bed deposition, and B the resuspension coefficient. Compartmentally averaged equilibrium concentration, S_*, may be calculated (Bijker 1968) through the compartmentally averaged flow velocity, $U_i=Q_i L_i/V_i$ (L_i is the length of the compartment), average depth (h_i), which is computed as the ratio of V_i to F_I, and sediment grain size. In this case, roughness of the bottom is calculated by the Manning friction coefficient.

The radionuclide transport in the compartment is described by equations of the dynamics of radionuclide concentrations in solution, C_i, on suspended sediments, C_i^s, and in bed sediment, C_i^b. Taking into account boundary conditions and exchange processes, the following equations may be written:

$$(11)\quad a_{1,3} = \frac{M_i^b}{1 + K_d \frac{M_i^b}{V_i}} \left(\frac{\delta_{1,3}}{\tau_{sb}} + \frac{\delta_{3,1}}{\tau_{dsb}} \right)$$

where τ_s, τ_{ds} are sorption and desorption parameters, respectively, in the water-suspended sediments system; τ_{sb}, τ_{dsb} are the same parameters for water deposits in the bottom. Parameters $\delta_{1,p}$ and $\delta_{p,1}$ determine the direction of the pollution movement:

$$(12)\quad \delta_{1,p} = \begin{cases} 1, & KC_i > C_i^p \\ 0, & KC_i < C_i^p \end{cases} \qquad (13)\quad \delta_{p,1} = \begin{cases} 1, & KC_i < C_i^p \\ 0, & KC_i > C_i^p \end{cases}$$

where p=2 for sediment contamination C^s and p=3 for bottom deposition C^b. The radionuclide transportation submodel contains six constants: K_s, K_d, τ_s, τ_{ds}, τ_{sb} and τ_{dsb}.

$$(7)\quad \frac{dC_i}{dt} = -C_i\left[\lambda + \frac{Q_*}{V_i} + \frac{1}{V_i}(K_s a_{1,2} + K_d a_{1,3})\right] + \frac{1}{V_i}\left[\sum_{j=1}^{m}(Q_j C_j)^t + Q_{i-1}C_{i-1} + a_{1,2}C_i^s + a_{1,3}C_i^b\right]$$

$$(8)\quad \frac{dC_i^s}{dt} = \frac{1}{V_i S_i}\left\{Q_{i-1}S_{i-1}C_{i-1}^s + R_i^h C_i^h + q_i^b C_i^b + K_s a_{1,2} C_i + \sum_{j}^{m}(Q_j S_j C_j^s)^t - C_i^s\left[a_{1,2} + R_i^h + q_i^b + Q_{i-1}S_{i-1} + \sum_{j=1}^{m}(Q_j S_j)^t + \lambda V_i S_i\right]\right\}$$

$$(9)\quad \frac{dC_i^b}{dt} = \frac{1}{M_i^b}\left[-C_i^b(a_{1,3} + q_i^s + \lambda M_i^b) + C_i^s q_i^s + K_d a_{1,3} C_i\right]$$

where $\lambda = \ln 2/T^*$ is the half-decay time. The exchange rate coefficients in this model are:

$$(10)\quad a_{1,2} = \frac{V_i S_i}{1 + K_s S_i}\left(\frac{\delta_{1,2}}{\tau_s} + \frac{\delta_{2,1}}{\tau_{ds}}\right)$$

When compared to long-term averages, the model WATOX predicted relatively well ^{90}Sr concentration (Marinets et al. 1995). Fig. 1 shows the results of parameter identification in WATOX for monthly experimental averages of ^{90}Sr concentration. Hereafter "^{90}Sr concentration " means concentration of ^{90}Sr in solutions since this radionuclide is hardly adsorbed by suspension. Also, the dissolved pollutant fraction typically exceeds 97% of the total quantity. Taking into ac-

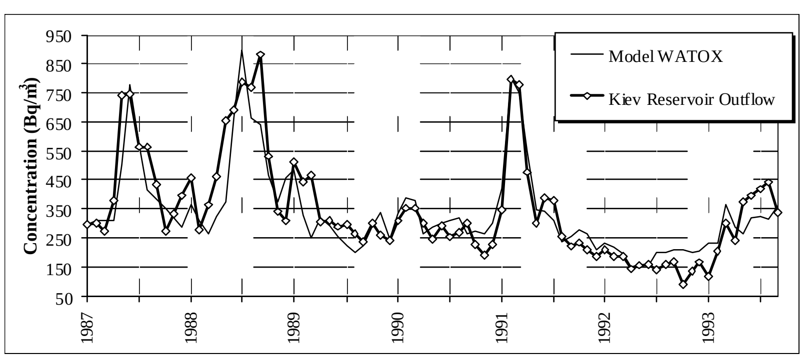

Fig. 1. Dynamics of ^{90}Sr concentration in outflow of the Kiev reservoir (monthly averages).

count that the annual average time of water mass transportation through the Kiev reservoir is 36 days, it is clear that the presented data are close to those averaged over a compartment, i.e. the same that the model calculates. However, the results are not so good when the model deals with short time averaged data. Fig. 2. presents parameters identification WATOX for the 1994 spring flood (daily data). These results indicate that processes taking place in a reservoir must be considered to improve the box model.

Figs 3, 4 shows a difficult situation during the 1994 spring flood (Voitsekhovitch et al. 1997), which resulted from a ice jam in the Pripyat river. The flood heavily contaminated territory near ChNPP and inflow concentration of ^{90}Sr increased rapidly to 5920 Bq/m^3 within five days from February 10. Water discharge in the Pripyat was 520 m^3/sec, which was relatively low.

^{90}Sr concentration increased up to 2553 Bq/m^3 during the spring flood that occurred from March 27 to April 22 of the same year. Water discharge increased up to 1700 m^3/sec, which was relatively high. As can seen in Fig. 4, ^{90}Sr concentration in the Pripyat and at the outlet of the Kiev reservoir reached the same peaks, but with some retention time. The first concentration was delayed by 28 days, the second one by 10. These delays coincided with the period it took for the contaminated water to flow through the reservoir. In the first case, the inflow, outflow and stream velocity in the reservoir were small and the time of contaminated water transportation rate was long. Thus, there was no instantaneous and complete mixing, but the transportation period had a strong influence. Contaminated waters reached the outlet of the reservoir for a period proportional to the transportation time. ^{90}Sr concentration for the second contamination peak grew larger than the first one, which implied mixing in some part of the reservoir during transportation. The degree of contamination per unit of time was smaller in the first peak because contaminated water discharge was very low.

3. MODEL UNDBE

I propose to develop a new model, UNDBE, that reflects the mixing taking place in some parts of the compartment to the moment of completion of transportation by changing V_i for V_i/n in equations (3), (7) - (9). For the new model, 1/n represents the effective part of the compartment in which water mixes during transportation time. In addition, a time-lag parameter, T_R, is used in equation (7) to account for transportation time. After the substitution, the equation becomes:

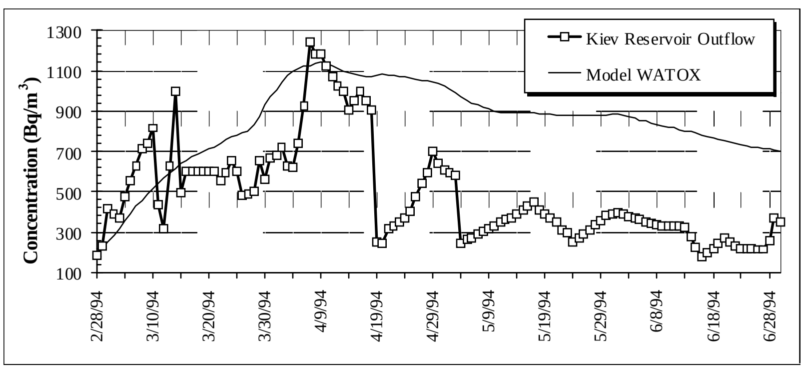

Fig. 2. Dynamics of ^{90}Sr concentration in outflow of the Kiev reservoir and WATOX results.

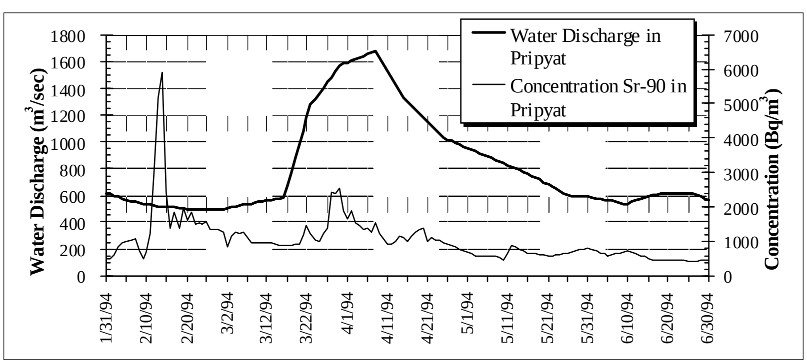

Fig. 3. Dynamics of water discharge and ^{90}Sr concentration in the Pripyat

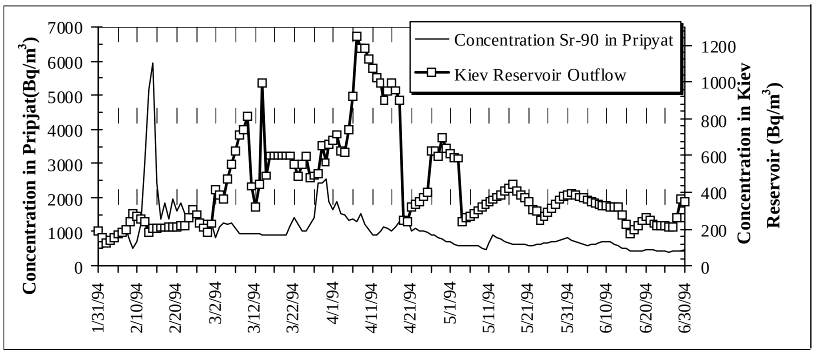

Fig. 4. Inflow and outflow concentration ^{90}Sr.

$$(14)\quad \frac{dC_i}{dt} = -C_i(t-T_R)\left[\lambda + \frac{nQ_*(t-T_R)}{V_i}\right] + \frac{nC_i}{V_i}\left(K_s a_{1,2} + K_d a_{1,3}\right) + \frac{n}{V_i}\left[\sum_{j=1}^{m}(Q_j(t-T_R)C_j(t-T_R))^f + Q_{i-1}(t-T_R)C_{i-1}(t-T_R) + a_{1,2}C_i^S + a_{1,3}C_i^b\right]$$

Such modifications lead to a system of ordinary differential equations with a time-lag parameter (T_R). In the new equation, C_i, C_i^s, C_i^b are concentrations averaged not over the total volume of the compartment but only over the 1/n part found at the outlet. UNDBE has the same six parameters as WATOX and a new one, n. The time-lag parameter, T_R, can be calculated through the mean flow U_i and length L_i of the compartment. This parameter is typically variable. There are very effective methods for the numerical solution of systems of differential equations with time-lag parameter (Hairer et al. 1987). A procedure similar to that of the RETARD model is used in UNDBE with some modifications made by the author, which allows the model to solve these equations with variable values of the time-lag parameter. The Dormand and Prince numerical method is used in the procedure. The simplicity of the box model and the use of effective procedure for solving equations allow the computation of the contamination transportation rate through the Kiev reservoir for a five month period in less than 1 second on a Pentium II/300. Thus, it becomes possible to solve the parameter identification task. The procedure RALG (Shor and Stetsenko 1989) was used to compute the minimum of the six-parameter function (n -fixed value).

4. RESULTS

Fig. 5 presents the results of the identification process for ^{90}Sr in the Kiev reservoir during the 1994 spring flood. The Kiev reservoir has a capacity of 3.7 km^3, is 70 km long, and has four main tributaries: Dniper, Pripyat, Uzh, and Teterev. In average, it is 4 m depth. Its maximum depth is 14.5 m. Daily data were used for water discharges, reservoir's level and concentration values in the modeling. A 3-cm effective thickness of the contaminated sediment was assumed. Initial bed sediment ^{90}Sr concentration was 550 Bq/g (Voitsekhovitch et al. 1997). The effective values of coefficients for the Kiev reservoir were: K_s = 0.6 m^3/kg, K_d = 1.1 m^3/kg, τ_s = 7 hours, τ_{ds} = 7 hours, τ_{sb} = 17 hours, τ_{dsb} = 9.6 hours and n = 12. In the case of determination of ^{90}Sr concentration, the model is more sensitive for changes in K_d, τ_{sb} and τ_{dsb} than in K_s and τ_s, which can be explained by the low adsorption of ^{90}Sr by susmination of ^{90}Sr concentration. The model is more sensitive for changes in K_d, τ_{sb} and τ_{dsb} than in K_s and τ_s, which can be explained by the low adsorption of ^{90}Sr by suspended sediments. Even better results may be obtained by decreasing bed sediment concentration of ^{90}Sr to 100 Bq/g (Fig. 6).

Exchangeable and nonexchangeable physical-chemical forms of radionuclides can explain the results in the solid phase. Only the exchangeable form of ^{90}Sr reacts with water. It is clear from Figs. 2, 5 and 6 that new modelling methods must be developed to simulate appropriately the contamination transport in the reservoir for short-time predictions. The squared-root mean deviation values and correlations between measurements and predicted values in Fig. 2 from March 5 to May 5 are $158 \cdot 10^3$ and 0.44, respectively. The same variables are $42 \cdot 10^3$ and 0.6 for Fig. 5 and $28 \cdot 10^3$ and 0.73 for Fig. 6. The model UNDBE turns into WATOX at $T_R \to 0$ and $n \to 1$. In this case it may used for long-term predictions with the same results as the ordinary box model.

CONCLUSION

The new model UNDBE can be used for various prognostic tasks, such as estimating the intensity and duration of pollutant action. The block of parameters identification gives the opportunity to derive the sets of parameters for which the model most reliably describes the pollutant transport. It contributes to in-

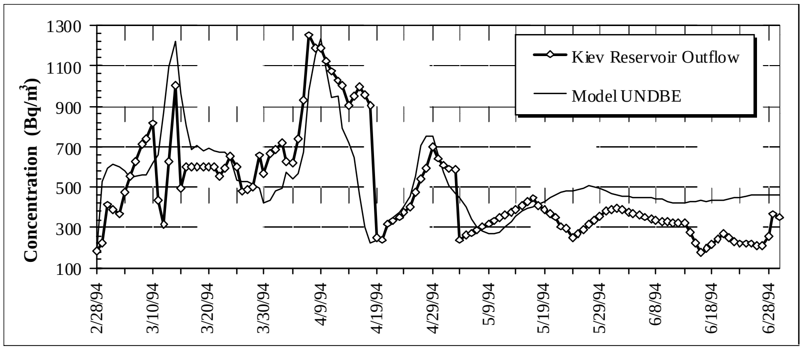

Fig. 5. Dynamics of ^{90}Sr concentration in outflow of the Kiev reservoir and UNDBE results.

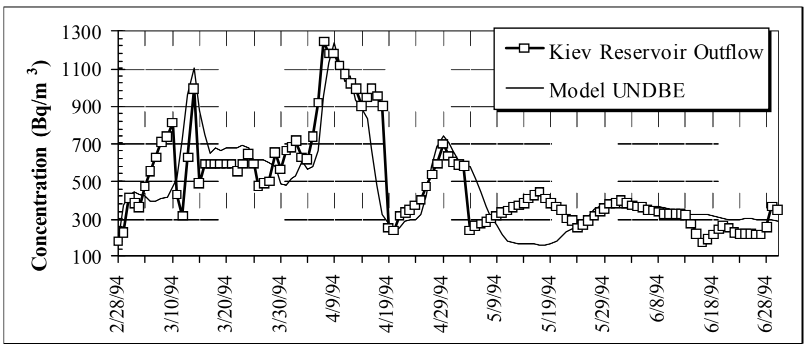

Fig. 6. Dynamics of ^{90}Sr concentration in outflow of the Kiev reservoir and UNDBE results after decreasing initial bed sediment concentration of ^{90}Sr.

crease the accuracy of the model and provides the possibility for adjusting to different reservoirs and types of contamination.

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Poster presentation and discussion session at the 2000 Annual ISEM Meeting

The 2000 ISEM meeting took place at the conference site of Ecosummit 2000 in Halifax, Nova Scotia, Canada, on June 18. As several societies met together for EcoSummit 2000, the idea was to have a separate ISEM meeting for one day before the different plenary sessions and discussion periods of the various working groups, which took place from June 19 to June 22. The ISEM meeting consisted of a poster session, a discussion period and a business meeting.

More than 15 posters on different subjects were presented at the poster session. Generally speaking, they covered the following topics: population dynamics, environmental risk assessment, effect of climate change, development of process-based models for plant ecosystems, diffusion of radioactive material in ecosystems and description of integrative methodologies based on geographic information systems, remote sensing technology and ecological models. The abstracts are included in the following section of the newsletter.

The highlight of the meeting was the discussion session on the following theme: "Application of systems analysis and simulation to address environmental issues of the 21st century." Three questions were introduced to open the debate:

- What role will modellers play in shaping up environmental policies?

Participants agreed that it is essential to develop stronger links between scientists and decision-makers. However, some pointed out that decision-makers do not necessarily base their decisions on models, despite the fact that Agencies involved in the decision-making process say that it is important to keep on developing models.

- How best to interact with other disciplines?

It was generally agreed that ISEM can help in the integrative process by getting involved in educational activities. For instance, ISEM could get involved in technology transfer activities for the general public, which could include case studies demonstrating that models have been used to solve problems. It will also be important to emphasize the process of modelling, not merely to consider models as products.

- What implementation strategies are required to ensure a broader application of systems analysis to address environmental issues?

The need to institutionalize the modeling process in laboratories was emphasized, similarly to existing organized entities. However, some participants mentioned that modellers could meet resistance from such organized entities. It will be important to define a theoretical framework to unite field and theoretical ecology and reductionistic and holistic approaches to address environmental issues. Above all, practical issues must first be addressed. Modellers need to learn how to involve stakeholders in the modelling process and to communicate with non-scientists, as model results can be particularly difficult to comprehend. Model documentation must be improved. We "modellers" must evaluate how credible we are.

Highlights of the business meeting

The business meeting took place right after the discussion period and several topics were discussed. Just the highlights are discussed here. Our treasury officer reported that ISEM finances are in good shape. As of June 2000, ISEM had about $27,000 in the bank account. Moreover, ISEM had just received royalties from Elsevier for the amount of $13,000. Some of this money will be invested in a market fund, as the motion was accepted by all. The Board of Governors decided to establish two awards: (1) ISEM Distinguished Service Award and (2) the George Van Dyne Award, after one of the founders of Ecological Systems Analysis. For 2000, the ISEM Distinguished Service Award was presented to Sven Jorgensen, the founder of ISEM, and the George Van Dyne Award was presented to Bernie Patten for his outstanding work in systems ecology.

New initiatives are taking place with Elsevier. First, we expressed our gratitude to Mary Malin, our liaison officer with Elsevier. Mary was leaving Elsevier for a new career. The names of all ISEM members were transmitted to Elsevier as potential reviewers for Ecological Modelling. As a general rule, an ISEM representative will be a member of the Editorial Board. There is a project on the drawing board to include models on the Elsevier web site. Thus, it will be important to develop protocols for documentation. Finally, it will be possible to have electronic subscriptions for Ecological Modelling. Other topics included the formation of a new Chapter in Australia and the possible establishment of a committee for student scholarships.

Scope of EcoSummit 2000

The aim of EcoSummit 2000 was to encourage integration of both the natural and social sciences with the policy and decision-making community, for the purpose of developing a deeper understanding of complex problems. This understanding will provide the basis for sustainable solutions to environmental problems. The structure of EcoSummit 2000 was unique in the sense that it was a Summit rather than a workshop or conference. All delegates were able to participate actively during the EcoSummit through Working Groups, in addition to the contributed poster sessions.

EcoSummit 2000 was centered around the following six Themes:

- Integrated modelling and assessment
- Complex, adaptive, hierarchical systems
- Ecosystem services
- Science and decision-making
- Ecosystem health and human health
- Quality of life and the distribution of wealth and resources

The organizing committee identified these Themes as necessary in reaching the goal of understanding and solving environmental problems in the 21st century. Each Theme agenda was developed in advance of the summit, and a Working Group on each of the six Themes was held during the course of the summit. The Working Groups were preceded by a Plenary session, where each Theme chair presented a state-of-the-art Plenary talk and posed the key questions which formed the basis of the Working Group agendas. On the final day of the Conference there was another Plenary session, at which the Rapporteurs summarized their Theme Working Group outcomes.

EcoSummit 2000 incorporated the 2000 ISEM International Meeting, the AEHMS 2000 Business Meeting, and the constituting meeting of the International Environmental Modelling and Software Society.

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Abstracts of ISEM posters at EcoSummit 2000
18 June 2000
Halifax, Nova Scotia
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ANASTÁCIO[1], P.M., L. MARTINS DA SILVA[2], J.P. MENINO[2], and J.C. MARQUES[3]. [1]IMAR Institute of Marine Research, c/o Department of Ecology, University of Évora, Rua Romão Ramalho, no. 59, 7000-671 Évora, Portugal; [2]INIA Estação Agronómica Nacional, Secçao de Melhoramento de Arroz, Quinta do Marquês, 2784-505 Oeiras; [3]IMAR - Institute of Marine Research, c/o Department of Zoology, University of Coimbra, 3004-517 Coimbra, Portugal. *Testing CRISP (Crayfish and Rice Integrated System of Production) - rice submodel and defining its validation status.*

The Crisp project (Crayfish and Rice Integrated System of Production) was developed in order to cope with crayfish infestations in rice fields, taking as an example the lower Mondego river valley (Portugal). Within the scope of the project several submodels were built, namely rice growth, crayfish population dynamics, hydrology, algae growth, and oxygen and nitrogen dynamics. The first version of the sub-model for rice growth, was not validated and therefore it should be tested with independent data before being used under different conditions. The structure of the model is based on the production of carbohydrates by photosynthesis. Parallel structures are used to simulate the development stage of the crop and the tillering process. The performance of the model is tested under different conditions i.e. with data collected independently in another region. Improvements on the model structure are discussed, namely the possibility of simplification or increase in complexity.

FLETCHER[1], C., G. HOWELL[2], L. INNES[3] and H. BREEZE[4]. [1]Gorsebrook Research Institute, Saint Mary's University, Halifax, Canada; [2]Environment Canada, Dartmouth, Canada; [3]Innu Nation, Sheshatshiu, Labrador; [4]Gorsebrook Research Institute, Saint Mary's University, Halifax, Canada. *Role for Cultural Landscape in Bridging Indigenous and Scientific Perspectives on the Labrador Environment.*

To contribute to the development of baseline ecological data for Labrador, Canada, researchers from the Innu Nation, Environment Canada, and the Gorsebrook Research Institute are jointly exploring links between indigenous ecological knowledge and scientific understanding of the environment. Among other things, baseline data are needed to meet the requirements of federal and provincial environmental assessment legislation in planning, assessing, and mitigating the effects of industrial development in the region. In this project, we have sought to develop an approach to ecological knowledge that is consistent with the landscape perspectives of one of the indigenous peoples of Labrador, the Innu. A central feature of this work is to foreground indigenous conceptions of the landscape. Elements within that are isolated and used to orient scientific investigations on aspects of the Labrador environment. Our poster will present some findings from a case study of ashkui, zones of early or permanent open water important in Innu land use.

Our project methodology must necessarily consider debates about the transmutability of meaning across cultures and the legitimacy attributed to various knowledge systems. Indigenous knowledge research faces challenges in interacting with other knowledge sources (Sillitoe 1998) and in gaining prominence in global political and ecological processes (Myer 1998). The process and use of indigenous knowledge research has also faced criticism when it comes to applying the products of the research (Howard and Widdowson 1996, Cruikshank 1998). Our research suggests that a cultural landscape approach provides a focal point through which different modes of ecological thinking can coalesce and interact.

GIRARDIN[1], P. and C. BOCKSTALLER[1,2]. [1]INRA, Equipe Agriculture et Environnement, BP 507, 68021 Colmar Cedex, France; [2]Association pour la Relance Agronomique en Alsace (ARAA). *How to validate an indicator?*

As any research tool, the indicators must be elaborated according to a scientific approach. One of the important steps of this elaboration is the validation. The overall objective of this presentation is to develop guidelines to evaluate the quality of indicators. According to the definition of an indicator, the indicators must be scientifically based and must achieve their two overall objectives: diagnosis and decision aid. Three kinds of validation are respectively presented: the "design validation" to evaluate if indicators are well founded, the "output validation" to assess the realism of the indicator as a tool of diagnosis, and, the "end use validation" to be sure the indicator is useful and used as a decision aid tool. For the "output validation" different tests are proposed, based on practical examples. If information is available, the validation can be done through comparison with external data: field data, model outputs, values of other indicators or expert data (*validation through comparison*). The multicriteria aspect of the indicators induced the use of expert judgements for validation when external data are not available (*global expert validation*).The implementation of the three types of evaluation is a part of the scientific elaboration of indicators.

KANG, D. and S. S. PARK. Ewha University, Seoul, 120-750, Korea. *Emergy cost-benefit evaluation of a proposed dam for water supply in Korea..*

A dam construction propossal was evaluated using the emergy concept to illustrate an application of this new concept in cost-benefit analysis of development proposals of natural environments in Korea. Emergy concept tries to evaluate the contributions of environmental resources to the real wealth of our economy. Models for emergy evaluation were constructed with the energy systems language, a symbolic modeling language that shows network properties of systems holistically. Water supply accounted for most emergy benefit of the dam construction. Increase in the aquatic productivity, another emergy benefit of the dam construction, was very minor in the total emergy benefit (less than 0.01%). Major emergy costs were in construction cost (28.2%), operation and maintenance (27.2%), social disruption (22%), and resettlement of people (12.5%). Emergy yield ratio was 1.06 when sediments were not included, and 1.02 when sediments were included. Emergy cost-benefit evaluation yielded less benefit for the proposed dam construction compared to that evaluated by the traditional cost-benefit analysis, 1.62. This study illustrated a new methodology in assessing effects of development proposals of natural environments in Korea.

KING, A. W., S.D. WULLSCHLEGER, and W.M. POST. Oak Ridge National Laboratory, USA. *Temporal rescaling of physiological process functions in global terrestrial ecosystem models.*

Simulating the terrestrial biosphere's role in the global cycling of carbon, water and energy using mechanistic process models has certain advantages. These models describe fundamental plant and soil processes at empirically accessible time and space scales for which we have the greatest understanding of process and the greatest ability to test our models. In addition, the temporal resolution of these models (seconds to hours) provides, in principle, a more accurate representation of plant, soil, and ecosystem process important in global biogeochemistry (e.g., diurnal patterns of water and CO_2 exchange with the atmosphere). With these advantages, however, come certain disadvantages. Physiologically-based models are (1) difficult to parameterize globally, (2) require spatially extensive global data sets, and (3) suffer long execution times. For example, an ecosystem model requiring two seconds of execution time per simulation year, not an unreasonable requirement for models of this type, will require 12 hours per simulation year for a global simulation on a 1 degree resolution grid. A 100 year simulation scenario will take 50 days to execute, and initial spin-ups of > 2000 years can be very lengthy indeed (33 months!). There are advantages to rescaling these fine resolution models to coarser time scales (e.g., hourly to daily or even monthly). Not only can global execution times be reduced, but we also gain understanding of how fine-scale processes are expressed at coarser time scales, and what information and accuracy might be lost using ecosystem models with coarser time steps. We describe an explicit temporal rescaling of hourly time step canopy fluxes in GTEC 2.0, a global terrestrial ecosystem model. We aggregate hourly results to coarser time scales and then develop response-surface models of the aggregated results. In this manner, an hourly time-step model is explicitly rescaled to generate a daily or coarser time-step model. We describe the development of the rescaled models, and we compare hourly time-step simulations of global canopy CO_2 and water flux with simulations from rescaled daily, weekly and monthly time-step models. Rescaling of gross primary production from an hourly to a daily time step resulted in a speedup factor of approximately 36. We discuss the trade off between loss of precision in the resolution of ecosystem fluxes and the reduction in global execution times.

KUNZ [1], M., M. DEPTYLA[2], A. NIENARTOWICZ[2] and W. PLICHTA[2]. [1]Nicholas Copernicus University, Institute of Geography, Laboratory of Remote Sensing and Cartography, Gagarina 5, 87-100 Torun, Poland; [2]Nicholas Copernicus University, Institute of Ecology and Environment Protection, Laboratory of Ecological Modelling, Gagarina 9, 87-100 Torun, Poland. *A Landscape Level Comparison of Soil and VegetationCarbon Content in 19th Century Pastoral and Current Managed Forest Landscapein Tuchola Forest (Pomerana, Poland).*

There can be distinguished three phases in the last 400 years of vegetation history in the north part of Tuchola Forest. Phase one was marked by the existence of vast forest complexes. Phase two, which lasted from 17th to the nineties of the 19th century, is the period of deforestation and agricultural utilisation on a large scale. Phase three was a period of afforestation and intensive forest cultivation in that area. The afforestation of soils, used for a time for farming, was done by the Prussian government at the end of 19^{th} and the beginning of 20^{th} century, when, mainly within the framework of the political action “Kulturkampf”, Zwangshof Forest District was formed. It was developed by buying out large numbers of Polish privately owned land estates and setting up state-owned forest plantations. Some farming areas were afforested by landowners, both before World War I and between the two World Wars, when the area under study was part of the restored Polish state. Shortly after World War II, under the land reform carried out after the change of political and social situation in Poland, more land estates, now state-owned, were afforested. As a result of the above activities, particularly those carried out by the Prussian government, the landscape structure was rapidly transformed. Vast plantations of Scots pine were introduced in the place of arable fields and poor sheep pastures.

We estimated (within the grant of Polish Government Scientific Committee 6P04 F 01313) the state of 1874 and current vegetation and organic and mineral soil carbon content in a large secondary forest landscape located in the northern part of Zabory Landscape Park and in the vicinity of Tuchola Forest National Park. Utilizing current forest stand information, old Prussian maps and inventory data, landscape level C estimates were made for each time period and the changes in vegetation and soil C over 125 years interval were quantified.

The information concerning soil, forest type and age class was entered into a geographical information system (GIS). The set of data obtained from maps and documents was supported by the results of current analyses of soils, treestands, and ground vegetation. High and low C levels were assigned to soils based on forest type and age class groupings. The overstory biomass was calculated on the basis of inventory data and of ratio of total to merchantable biomass of trees. The density and height of tree and shrub species were noted in 1 ha sample areas in forest of different type and age, and the relationships between height and biomass according to species were used in estimating of the biomass of the understory. The biomass of ground vegetation values were calculated onthe basis of five sample quadrates 50x50 cm taken in each forest type and age class. Current levels of C in soil and vegetation in small areas of the remaining meadows, pastures and fields were used in estimating the carbon content in present and 19^{th} century landscapes. The coefficients of C content in species biomass units were obtained from literature describing the ecosystems of the study area.

The value of total carbon content in existing soils on the landscape level was calculated as the sum of products of polygon sizes by carbon contents according to vegetation type and age class occurring on the soils. The total carbon content in vegetation was calculated as the sum of carbon content in overstory, understory, and ground vegetation recorded in each polygon. Estimates for both landscapes revealed that C content in current landscape is over five times higher than C content before the setting up of the Prussian Zwangshof Forest District as a results of changes in land use and especially in forest cover.

LAROCQUE, G. R. Natural Resources Canada, Laurentian Forestry Center, P.O. Box 3800, 1055 du P.E.P.S., Sainte-Foy, Quebec, Canada. *Modelling the carbon cycle in sugar maple (Acer saccharum Marsh.) stands with detailed photosynthesis, evapotranspiration and nitrogen cycle sub-models.*

A process-based model that includes detailed photosynthesis, evapotranspiration and nitrogen cycle sub-models was developed for sugar maple (*Acer saccharum* Marsh.) stands in Eastern Canada. The photosynthesis sub-model is based on the Farquhar and von Caemmerer model and includes equations that represent, at different sections of the canopy, the effect of temperature and different forms of foliage nitrogen content on the maximum rate of carboxylation allowed by Rubisco and the light saturated potential electron transport rate. The verticalvariation in leaf biomass and area was described using the Weibull distribution function in order to simulate photosynthetic rate in different sections of the canopy by using a radiative transfer approach. The nitrogen sub-model simulates nitrogen mineralization and transfers in the soil and vegetation. The nitrogen cycle is intimately related to above- and below-ground carbon partitioning. Parameterization of the model involved the establishment of permanent field stations for the measurement of photosynthetic rate at different sections of the canopy, measurement of foliage, stem and root respiration and the hourly monitoring of meteorological variables. Temporary sample plots were also established for the derivation of basic allometric relationships. Sensitivity analysis indicated that the model is sensitive to variations in temperature, solar radiation and foliage nitrogen content within the canopy.

MATEJICEK, L. Institute for Environmental Studies, Charles University Benatska 2, Prague 2, 128 01, Czech Republic. *Development and Parameter Estimation of Spatial Ecological Models with GIS and Remote Sensing.*

The spatial dynamic models are developed with a set of reaction-diffusion equations. Replacement of the reaction terms by the multi-species logistic growth results in interactions of higher order. A set of logistic growth, reaction-diffusion equations, is used as a case study for analytical description of patchy population dynamics to changes in model parameters. In addition to the logistic growth, delayed variables are used to simulate age structure and long-distance migration. Basic estimation of model parameters is carried out by spatial classification of aerial photographs and other data sources. In spite of that remote sensing in the form of aerial photography has been used for more than half a century, the availability of multispectral scanner, radar data and satellite technology has created a tremendous increase in the field of data analysis. Estimation of diffusion, convection, carrying capacity and growth parameters combines the recent and significant developments in GIS and remote sensing technology. The interrelationships between field and remote observations have created additional dimensions in model development and parameter estimation. This approach is documented in the frame of a GIS project. A number of population and community models have beendeveloped to simulate reaction-diffusion phenomena with various interaction effects. The model example is focused on energy flows on a level of ecosystems. The aspects of temporary spatial data for model development and estimation are discussed. Model verification and prediction precision are also included in the discussion.

MCCOMISH, T.S., ALLEN, P.J., SHROEY, S.M., and LAUER, T. E. Aquatic Biology and Fisheries Center, Ball State University, Muncie, Indiana 47306 U.S.A. *A Yellow Perch Population Simulation Model for Southern Lake Michigan*

Abundance of the yellow perch *Perca flavescens* in southern Lake Michigan has declined precipitously in recent years to a low, remnant population. Yellow perch are considered a valuable sport and commercial species in southern Lake Michigan. Efforts to curtail the decline in yellow perch abundance resulted in closure of the commercial fishery in 1997. To better understand the dynamics of the yellow perch population and assist the Indiana Department of Natural Resources with harvest policy decisions, we developed the Indiana Lake Michigan Yellow Perch Simulation Model. Model design was established using Stellaâ Research software. Male and female yellow perch are modeled separately within the model. Variables included within the model that affect yearly changes of both sexes in the population include density-dependent growth, spawning stock abundance, alewife *Alosa pseudoharengus* (a predator/competitor of larval yellow perch) abundance, natural mortality, harvest, and bycatch. Index trawl sampling data for the years 1984-1999 were used to validate the model. Simulations were conducted using various levels of harvest, bycatch, and alewife densities. Results indicate that when alewife densities are moderate to high, yellow perch densities are suppressed. During periods of low yellow perch densities, when annual harvest exceeds 60% of fish $ 200 mm, female cohorts may be extirpated by age 4. Bycatch of yellow perch 165-199 mm has a negative impact on the yellow perch regardless of the population density. The recovery and future sustainability of the yellow perch population in Indiana waters of Lake Michigan will be dependent on low mean alewife density and the careful regulation of harvest and bycatch.

NAESLUND[1], B., L. KUMBLAD[1], M. GILEK[1] and K. ULRIK[2]. [1]Department of Systems Ecology, Stockholm University, Stockholm, Sweden; [2]Swedish Nuclear Fuel and Waste Management Co. (SKB), Stockholm, Sweden. *An ecosystem based model for the transport and fate of radioactive caesium in a coastal area of the Baltic Sea, Sweden.*

A model for the transport and fate of radioactive caesium (e.g. 135-Cs) in a coastal ecosystem of the Baltic sea is described and evaluated. The model deals with Cs-fluxes in benthic and pelagic organisms as well as in abioticcompartments such as sediment and water. The purpose of the model is to estimate radiation doses to aquatic organisms and humans following a theoretical release from a repository for radioactive operational waste. Uptake and excretion of caesium is modelled using size adjusted physiological mechanisms, coupled to a dynamic carbon-flow model.

Organism groups, e.g. plankton and fish, are modelled as compartments that interact dynamically with each other and with the environment e.g. through water exchange. When compared to the commonly used bioconcentration factors, this dynamic modelling approach provides higher resolution and better understanding of important transport pathways such as water exchange, sedimentation and food-web transport. Furthermore, since the model is based on general ecosystem properties it can be used to evaluate a multitude of future scenarios and thereby provide vital information for the safety assessment of nuclear waste.

ODULAJA, A. International Centre of Insect Physiology and Ecology, PO Box 30772, Nairobi, Kenya. *Modelling the trappability of insects in relation to distance from their natural habitats.*

Traps are in widespread use for the control and survey of insect populations. Many basic ecological studies have been carried out in the natural habitats of different insects with the aim of developing effective trapping technologies. An understanding of trappability in relation to habitat is therefore necessary for optimum trap placement for both monitoring and suppression of insect populations, and for studying ecology and behaviour of the insects.

Most insights on this issue have come from conventional analyses of numbers or percentages of insects caught at different distances from their habitats. Such analyses are only indicative; they lack the ability to predict optimum positioning or radius of attraction of the traps.

To address these issues, models capable of predicting optimum trap position or radius of attraction of a trap, in relation to insects' habitats, were sought. The log-logistic probability distribution function

$$f(z) = [\frac{1}{\sigma}\exp(\frac{z-\mu}{\sigma})] \,/\, [1+\exp(\frac{z-\mu}{\sigma})\,]^2$$

readily satisfies the required properties of such a model. This distribution also has an added advantage of its capability to handle both right- and left- censoring, since the likelihood can be expressed as a special form of binomial likelihood. This is particularly applicable to this situation, in that not all distances inside and outside the habitats can be considered.

The model fitted well to a series of observed field data, and enabled the estimation of optimum trapping distances from the different vegetation types for *G. f. fuscipes* along the shores of Lake Victoria, Kenya. The parameters were obtained using the non-linear maximum likelihood approach. Simulation techniques were then used to estimate the radius of attraction of the trapping device for the insect, taking into consideration the efficiency of the trap.

PARK[1], R.A., J.S. CLOUGH[1], D.A. MAURIELLO[2], M.C. WELLMAN[2], W.D. TATE[2] and A. STODDARD[3]. [1]EcoModeling USA; [2]US Envi ronmental Protection Agency, USA; [3]Stoddard & Associates, USA. *Quantifying Risk and Recovery in Aquatic Ecosystems With an Integrated Modeling Framework.*

An integrated fate and effects simulation model, AQUATOX, has been greatly enhanced to assess the potential risk to aquatic ecosystems resulting from exposure to multiple natural and anthropogenic stressors. The model integrates aquatic ecosystem, chemodynamic, bioaccumulative, and ecotoxicologic modules, and a probabilistic risk calculator into a flexible interactive assessment tool. It can simulate the simultaneous effects of up to 20 toxic chemicals and conventional pollutants on as many as 34 algal, macrophyte, invertebrate, and fish groups plus up to 15 age classes of one game fish in 10 aquatic segments.

This poster will illustrate validation and application of case studies integrating the AQUATOX model into a decision making framework for managing releases and remediation of toxic substances and nutrients in aquatic ecosystems. This process involves the assessment of risk across hierarchical spatial and temporal scales, and the selection and evaluation of management options for their potential impact on system recovery. Examples will include multiple impacts of pesticides and nutrients from agricultural runoff on a reservoir; impacts of municipal and industrial discharges on a eutrophic lake; and natural recovery from PCBs in linked reaches of a stream.

PARK[1], S.S., Y. M. NAH[1] and C.G. UCHRIN[2]. [1]Ewha University Seoul 120-750, South Korea; [2] Rutgers University, New Brunswick, New Jersey 08903, USA. *Application of an Oxygen Equivalent Model to the Water Quality Dynamics of a Macrophytes Growing River.*

A water quality modeling study was performed in a macrophyte dominated water body. A computer model, SIREM2 (Shallow Imppounded River Eutrophication Model, version 2) was formulated to incorporate dissolved oxygen changes and nutrient uptake/recycle caused by macrophytes. In this model, the total amount of aquatic plants is represented dynamically as an oxygen equivalent, dependent upon available solar radiation. The model simulates 7 coupled abiotic state variables and 2 independent variables, which include BOD (CBOD or 5-day BOD), DO (daily average value or diurnal variation), (organic nitrogen, ammonia nitrogen, nitrite/nitrate nitrogen, total organic phosphorus), dissolved inorganic phosphorus, a 1 st order decaying substance, and a conservative substance. The model was apllied to the Matchaponix Brook - Duhernal Lake system, located in central New Jersey, USA, where macrophytes played an important role in the water quality dynamics. In order to validate the model formulation, USEPA's QUAL2E was applied to the same system and the results from the two different models were compared. Comparison of the model results indicated that the SIREM2 model would present the function of aquatic plants in diurnal DO variations, nutrient uptake/recycle, and the generation of autochtonous organic matter, better than the QUAL2E model. The model was field validated to data collected during synoptic surveys conducted during the summer of 1999.

PARKER[1], P., I. ROWLANDS[1] and D. SCOTT[2]. [1]Faculty of Environmental Studies, University of Waterloo, Waterloo, Ontario, Canada N2L 3G1; [2]Adaptation and Impacts Research Group, Environment Canada, Waterloo, Ontario, Canada N2L 3G1. *Integrating technical and behavioural studies in the residential energy sector, Canada.*

Our present pattern of energy production and consumption is unsustainable. With the increased recognition of global climate change, the need to re-evaluate the environmental, economic and social dimensions of the energy system is particularly apparent. The residential sector accounts for the largest share of personal energy consumption in Canada and emitted an estimated 71 million tonnes of carbon dioxide in 1996. Proposals to reduce greenhouse gas emissions often cite potential improvements of 20-30% in this sector. However, in order to achieve these potential savings both technical and behavioural studies need to be integrated. The study integrates technical and behavioural research at a regional scale, using Waterloo Region (population 400,000) as a case study. Data was used from the detailed technical assessment (EnerGuide for Houses) of 1000 houses and social surveys of the residents' attitudes and behaviour toward energy use and preferred source of energy ('green' or traditional supplies). The first commercial offering of residential "green power" in Ontario took place during the study and illustrates the potential for changes in public perception. By situating the technical potential for energy efficiency in the residential sector within a localized social context, the research identifies and measures the socio-technical potential to save energy and reduce CO_2 emissions in Waterloo Region and offers a model for adaptation and use in other regions. In other words, by integrating community specific information on the existing housing stock, its energy efficiency potential, established energy conservation norms, the social acceptability of various energy efficiency technologies, public preferences for energy supplier characteristics, community renewable energy options, and major energy consumption influences like population growth and climate change, future community energy profiles and pathways toward sustainable energy futures can be developed and evaluated.

UTSET, A.[1], A. DELVALLE[1], J. LÓPEZ[2] and C. RINCONES[3]. [1]Agrophysics Research Unit, Agricultural University of Havana (UNAH), Apdo. 18, San José de las Lajas, La Habana 32700, Cuba; [2]Institute of Geography, National University of Mexico (UNAM), Mexico City, Mexico; [3]National Resource for Agricultural Research (FONAIAP), Maracay, Venezuela. *A sugar-cane mechanistic model as a decision-maker tool under variable environmental conditons.*

A mechanistic sugar-cane yield simulation model is presented. The model is based on the Dutch model SWAP, including the sugar cane crop functions as determined experimentally in Cuba. A model validation performed with data from Cuba, Mexico and Venezuela is shown. The model is connected to a Cuban-made weather generator in order to provide the daily climate data input of the model. An interface between the model and the Geographic Information System (GIS) ILWIS was also done, which facilitates the model input/output procedures. Several model applications in selecting the best sugar-cane management option in variable environmental conditions are shown. These applications comprise, among others, prediction of sugar-cane yields under El Niño – South Oscillation (ENSO) appearance for several soil types, selecting the best irrigation and/or drainage solutions for each field in a whole sugar-cane farm under typical or variable weather conditions, as well as soil salinisation risk and groundwater pollution assessments for irrigated sugar-cane fields with shallow water tables. The advantages of using mechanistic instead of functional models are pointed out. The model provides an effective tool for decision-making in sugar-cane cropping.

Book Review

"*Geographic Information Systems. An Introduction*," by Tor Bernhardsen, John Wiley and Sons, Inc, New York, 1999, ISBN 0-471-32192-3 (hardback) 372 pp.

Recent growth in popularity of Geographic Information Systems (GIS) has resulted in a wealth of new textbooks aiming at providing comprehensive introduction to the subject (see the end of this article for a list of the most recent offerings). Each of these texts was of course written from an unique viewpoint and in a particular style, depending on the training of the author. Since GIS practitioners come from a wide variety of disciplines (geography, cartography, earth sciences, engineering, computer science), these viewpoints can be quite different. Also, many of the essential concepts and much of the terminology associated with GIS are still under debate, further fuelling the differences between the texts.

When assessing any particular GIS text, one must consider how it compares to the others on offer. In their text Fundamentals of Geographical Information Science, Burroughs and McDonnell employ a scholarly style to cover selected aspects of the theory of spatial analysis in relatively more depth than the other texts. In contrast, Berry's offering, Spatial Reasoning for Effective GIS, uses a light-hearted style to present GIS concepts at the level of the real world, non-academic practitioner. Chrisman's Exploring Geographic Information Systems and DeMers' Fundamentals of Geographic Information Systems fall between these two extremes, aiming to cover a wide range of the key issues associated with GIS while maintaining a focus on GIS analysis techniques. All of the texts mentioned thus far approach the explanation of GIS from primarily a geographical viewpoint, with Burroughs treating spatial analysis (what you actually do with GIS) in the most depth, and DeMers and Chrisman treating it with the most breadth. Finally, a more applied book, Geographical Information Systems for Ecology, offers a limited introduction to GIS geared particularly towards ecological researchers.

None of the above books, however, cover the computing aspects associated with GIS in any great depth other than the requisite discussions about database structures for spatial data. This is where the overall strength of Bernhardsen's Geographic Information Systems. An Introduction lies – it is the first introductory GIS text I've seen that includes a comprehensive treatment of the computer science theory relevant not just to using the GIS for spatial analysis, but also to building and maintaining the system. For example, there is an entire chapter on hardware (Chapter 7), on software (Chapter 8), on database implementation (Chapter 12) and on selecting and implementing a GIS (Chapter 18). These chapters provide valuable information just touched upon in the other texts. Indeed, Bernhardsen's book appears to be crafted from a computer science perspective, focusing on GIS as a spatial information system. Yet at the same time, Bernhardsmanages to cover most of the important spatial/geography issues associated with GIS (with some important exceptions which are discussed later in this review). Thus, the book represents a reasonably good compromise between coverage of the spatial and computing issues of GIS, while remaining at the introductory level. This is in contrast to the other two notable computing-oriented GIS texts. An excellent treatment of GIS-related computing issues is provided by Worboy's text, GIS: A Computing Perspective, but its focus is 'unashamedly biased towards the computational aspects of GIS', with the reader directed to other books for the geographical perspective. The other offering, Laurini and Thompson's Fundamentals of Spatial InformationSystems, also presents GIS (termed geomatics) as an information system, with a detailed academic treatment of relevant computing concepts. However, their book is more of an advanced text and lacks discussion of the real world issues and implications of using GIS (such as data quality and standards) than Bernhardsen's book handles well.

The strength of Berhardsen's treatment of computing issues, however, can be a weakness as it comes at the expense of the coverage of geographical issues. Most notably absent was any discussion of the integral concepts of spatial scale and resolution - in fact, neither of these were even listed in the book's index. Further, another essential concept - topology - is only briefly mentioned in a chapter about data management (Chapter 13) and is never defined in the context of GIS. Given that the ability to store and analyse topology is a major defining quality of a GIS, I find this a serious omission. Accordingly, I disagree with Bernhardsen's statement that a GIS is 'any computer system that deals with geographic data'. By this definition a simple spreadsheet or word processing program could be called a GIS as long as geographic coordinates were included with the data! Finally, and most importantly, spatial analysis techniques are explained in just two short chapters (Chapters 14 and 15). Yet the geographically oriented books took an average of six chapters to cover the same material.

So, although the author stresses in the introduction that the book is aimed at first time GIS users, it assumes mastery of key geographic concepts (much like most of the other texts assume mastery of basic computing concepts or a computer technician on hand). While one might hope that the average graduate (or any other person for that matter) would have mastered such important basic geography skills, the reality is that many people who are using (or plan to use) GIS have not. An even greater number of people may be unfamiliar with the full range of spatial analysis tools on offer in most GIS. This is evidenced by the present situation where many GIS are vastly under utilised (often as glorified cartographic machines) due to lack of knowledge of their capabilities.

With that in mind, this book would be extremely useful to train a technician hired to build and maintain a GIS – someone who doesn't actually use GIS for analysis but needs to know just enough to trouble-shoot and assist users. The book would also serve as a valuable supplementary GIS reference (with one of the more geographically oriented texts as the main book), particularly for those who plan to use advanced GIS tools (such as ecological scientists). Otherwise, the book would be an excellent first text for those already well versed in geography and spatial analysis (but for some reason not yet familiar with GIS). For those charged with teaching an introductory GIS subject, this text could be valuable as long as used appropriately given the background of the students.

In general, the book is well organised with simple, yet effective visual aids (often a challenge when explaining GIS concepts). Also, unlike many of the recent GIS texts, there is a chapter on the history of geographic data and GIS (Chapter 2) and one on the future of GIS (Chapter 21) although the latter is rather limited. For instance, Bernhardsen identifies improvements in technology as a trend, but fails to mention the need for associated advances in the geographic science behind that technology to ensure that GIS tools are used effectively. Other strengths of the book include the treatment of spatial data models (Chapters 4 and 5). These integral concepts are presented in a succinct and accessible manner, which leads on naturally from the basic to the more advanced (important as most new GIS users struggle with these concepts). One example of this is a section in Chapter 4 that helps users choose between raster and vector formats which is particularly useful. In addition, the book's coverage of the range of methods of data collection (Chapters 9 and 10), and data error (Chapter 11) is relatively comprehensive. Finally, the book includes a very important chapter detailing the development of standards for spatial data, which, though missing from the other texts, is a vital issue in the use of GIS today and into the future.

In summary, it appears that despite the proliferation of introductory GIS texts now available, no single book adequately covers all aspects of GIS. Given the complex and multi-disciplinary nature of the subject, perhaps that is to be expected. Regardless, I strongly recommend Bernhardsen's book as a GIS text, given the considerations discussed above.

Recent GIS Text books

Bernhardsen, Tor, 1999, *Geographic Information Systems*. An Introduction, John Wiley and Sons, Inc, New York, 372 pp.

Berry, JK, 1995, *Spatial Reasoning for Effective GIS*, GIS World, Inc, Fort Collins, Colorado, 208 pp.

Burrough, PA and McDonnell, RA, 1998, *Principles of Geographical Information Systems*, Oxford University Press, New York, 333 pp.

Chrisman, N, 1997, *Exploring Geographic Information Systems*, John Wiley and Sons, New York, 298 pp.

DeMers, M., 1997, *Fundamentals of Geographic Information Systems*, John Wiley and Sons, Inc., New York, 486 pp.

Laurini, R and Thompson, D, 1994, *Fundamentals of Spatial Information Systems*, Academic Press, Sydney, 680 pp.

M. Puotinen, *School of Tropical Environment Studies and Geography*, James Cook University, Townsville, QLD, Australia.

Worboys, MF, 1995, *GIS: A Computing Perspective*, Taylor and Francis, London, 376 pp.

Publication Information

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