Cooperation in Long Term Ecological Research in Central and Eastern Europe

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Cover illustration: The polluted regions of the rivers studied in the Eastern-tributaries of the Tisa River. Figure 1 from "The ecological state of the Eastern-tributaries of the Tisa River - based on characteristics of the physico-chemical parameters, the flora and fauna" by Andrei Sárkány-Kiss and Kunigunda Macalik.

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PREFACE

Long-term, cross-system data are now recognized as crucial to our understanding of environmental change and management. Cross-site research within the Long Term Ecological Research (LTER) network has led to insights into patterns of biodiversity and primary production, controls on pollutant leaching from natural watersheds, hydrologic controls on nitrate export, and many other issues relating to global change. The LTER network has long realized that cross-site research offers scientists the opportunity to make generalizations about ecological phenomena, and to test the validity of local findings. The International LTER (ILTER) Network was formed with a mission to facilitate international cooperation among scientists engaged in similar long-term ecological research. The main objectives are to promote and enhance understanding of long term ecological phenomena across national and regional boundaries, facilitate interaction among participating scientists across sites and disciplines, promote comparability of observations and experiments, contribute to the scientific basis for ecosystem management and improve predictive modeling at larger spatial and temporal scales, assist in the establishment of networks for long-term ecological research in other countries, and create programs and scientist exchanges between U.S. and foreign LTER sites and networks.

This volume reports the proceedings from a workshop held in Budapest, Hungary, from 22-25 June, 1999, titled "Cooperation in Long Term Ecological Research in Central and Eastern Europe". The goal of this workshop was to promote a regional ILTER network of sites and research questions in the Carpathian Basin region, involving The Czech Republic, Hungary, Poland, Romania, Ukraine, and Slovakia, and Estonia. This workshop brought together scientists from these different countries and from the US to share research ideas, plan linked experiments and measurements, discuss potential ILTER sites in countries without formal ILTER programs, introduce scientists from different countries to each other and to the other ILTER sites, and to share data management and networking programs. The Carpathian Basin ecoregion is a fairly consistent physico-geographical unit, still rather rich in biota and with relatively high biodiversity. This region, due to its distinct and intensive patterns of land use and its environmental history, offers scientists a unique opportunity to test and expand models linking land use history to biogeochemical cycling and nutrient use, air pollution to ecosystem structure and function, and perhaps even anthropogenic effects of air pollution and land use to biodiversity. It is the belief of the organizers of this conference that having linked experiments and observations across a broad region can increase the chances for significant EEU funding of collaborative research, promote the positive exchange of research ideas and techniques among participants, and bring to international attention the research in these ILTER sites.

Presentations were given on highly successful networks already in place in Europe and several international initiatives, including DIRT, EXMAN, IBOY and the GTOS NPP Demonstration Project. Proposals for specific research networks in Central Europe, such as DIRT and a Central European forest ILTER, were discussed. Scientists from Romania presented preliminary plans for a long term ecological research network in Romania, and Estonia described an environmental monitoring network. A number of examples of LTER activities in participating countries were given, including collaborations within CE countries and with the US. Finally, breakout groups gathered along disciplinary lines to discuss future collaborative efforts.

We hope that this meeting will serve as a starting point for the establishment of networks for long-term ecological research in Central European countries, and for the creation of programs and scientist exchanges between U.S. and foreign LTER sites and networks. For logistical and financial support, we would like to thank NSF International Programs, the US EPA, the US-Hungary Science and Technology Program, the Hungarian Academy of Sciences and its Ecological Centre in Vácrátót, the ILTER Network Office (and many thanks to Patty Sprott), and Oregon State University (particularly Janet Squire).

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Nitrate Leaching from European Forests: Results and Lessons from NITREX and Other Cooperative Projects in Western Europe

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Scientific Results

Three different data sets on input-output fluxes of nitrogen (N), soil N storage and vegetation characteristics from European forest ecosystem were used to illustrate the extent of nitrate leaching and to analyse relationships between nitrate leaching/N retention, N input and ecosystem characteristics. Detailed process studies and ecosystem manipulation experiments performed at five sites within the EC funded NITREX (Nitrogen Saturation Experiments) project (Wright & Rasmussen, 1998) were used to formulate hypotheses and relationships which are tested on i) data compiled from 70 European forest ecosystem studies (ECOFEE database), and ii) data from a regional survey of nitrate leaching at 111 Danish forest sites.

In the NITREX project, N cycling processes were studied at five sites representing the European deposition gradient (13-59 kg N $ha^{-1}yr^{-1}$) as well as by simulating either increased or decreased nitrogen deposition over a period of 4-5 years at the sites (Gundersen et al., 1998a; Emmett et al., 1998). Significant correlations were found between a range of variables including N concentrations in foliage and litter, soil N transformation rates and forest floor characteristics. The N status at sites could be described by each of these variables or best described by combining the information from each ecosystem component in a summary variable. Nitrate leaching was significantly correlated with N status but not correlated with N deposition. Forest floor mass and root biomass decreased with increased N status. Characteristics of the mineral soil were not correlated with vegetation and forest floor variables. High C/N ratios in the mineral soil at the high N deposition sites suggest that the mineral soil pool changes slowly and need not change for N saturation to occur. The changes in N concentrations and fluxes after either increasing or decreasing the N input followed the direction expected from the site comparison: increases at N addition and decreases at N removal sites. Changes in nitrate leaching were small at the low N status sites and substantial at the high N status sites.

The ECOFEE (Element Cycling and Output-fluxes in Forest Ecosystems in Europe) data compilation gave a representation of N cycling in forests in Central and Northwest Europe where N deposition is elevated (Gundersen, 1995). Sites with high N deposition (up to 64 kg N $ha^{-1}yr^{-1}$) were characterised by high input of ammonia/ammonium. The deposition of oxidised N was usually only 10 to 15 kg N $ha^{-1}yr^{-1}$. Of all the sites included, 60% leached more than 5 kg N $ha^{-1}yr^{-1}$. Elevated nitrate leaching appeared at inputs above 10 kg N $ha^{-1}yr^{-1}$. At several sites with inputs of 15-25 kg N $ha^{-1}yr^{-1}$ nitrate leaching approached the N input, whereas ammonium dominated sites with high input still retained c. 50% of the input. On the regional scale (Denmark) soil nitrate concentrations were elevated at 30% of the sites (Callesen et al., 1999). High soil nitrate concentrations were clearly related to high N input.

Nitrate leaching and nitrate concentrations were negatively correlated with forest floor C/N ratios in both the European and the Danish dataset. Sites with a C/N ratio below 25 leached nitrate or had elevated nitrate concentrations. Nitrate was not present in the subsoil at sites with C/N ratios above 30. Forest floor C/N ratios may be used to assess risk for nitrate leaching in conifer stands using >30, 25 to 30, and <25 to separate low, moderate, and high nitrate leaching risk, respectively (Gundersen et al., 1998b).

Lessons

The scientific success of NITREX probably relied on many things of which I will especially mention:

- The project was focused on a clear problem 'effects of N deposition'.
- The project combined a gradient approach (low to high deposition) with a manipulation approach (N addition at low N, reduction by roof at high N). In this way findings from the gradient could be supported by experiments as well.
- Combining 'vertical and horizontal' responsibility for the science so each scientist (or group) was responsible for a site and also for an activity or measurement across sites.
- Sharing of data that allowed in depth integration across sites within several thematic areas headed by the investigator most qualified or having the time needed for writing an integration paper (Bredemeier et al., 1998; Boxman et al., 1998; Emmett et al., 1998b; Gundersen et al., 1998; Tietema et al., 1998).
- Emphasis on the personal/social side of science, using time to come to know each other over week-long workshops/camps where people worked together on the science and had some fun as well.

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Controls on Forest Soil Organic Matter Development and Dynamics: Chronic Litter Manipulation as a Potential International LTER Activity

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Introduction

Organic matter content strongly influences key soil properties such as aeration, moisture holding capacity, and cation retention in terrestrial ecosystems. It also contains large reservoirs of nutrients and reduced carbon that fuel microbial processes and support complex communities of soil and forest floor organisms. Because nutrient cycles are relatively closed in most forests, trees and understory plants depend much more on nutrients released from decomposing organic matter than on nutrient inputs to meet their nutritional requirements. Therefore, the amount and the quality of soil organic matter greatly influence primary production and biogeochemical cycles in forests.

Despite the importance of soil organic matter, the degree to which above- and belowground plant inputs influence its formation and dynamics is not well understood. To address this gap, we established a long-term study in of controls on soil organic matter formation in 1990 at the Harvard Forest LTER site in Petersham, Massachusetts, USA. We refer to this experiment as the DIRT (Detritus Input Removal and Transfer) project. Our **goal** is to ***assess how rates and sources of plant litter inputs control the accumulation and dynamics of organic matter and nutrients in soils***.

The DIRT treatments at Harvard Forest consist of chronically altering above- and belowground litter inputs to permanent plots in a mid-successional oak-maple-birch forest (Fig. 1). The experimental design is derived from a project started in 1957 in forest and grassland ecosystems at the University of Wisconsin Arboretum (Nielson and Hole 1963). Treatments are applied on 3m × 3m plots (n = 3) as follows:

Treatment	**Method**
CONTROL	*Normal litter inputs are allowed.*
NO LITTER	*Aboveground inputs are excluded from plots by raking.*
DOUBLE LITTER	*Aboveground inputs are doubled by adding litter removed from* NO LITTER *plots.*
NO ROOTS	*Roots are excluded by inserting impenetrable barriers in backfilled trenches to the top of the C horizon.*
NO INPUTS	*Aboveground inputs are prevented as in* NO LITTER *plots; Belowground inputs are prevented as in* NO ROOTS *plots.*
O/A-LESS	*Organic and A horizons are replaced with B horizon soil at the start. Normal inputs are allowed thereafter.*

The DIRT project is developing into a long-term, inter-site experiment. To that end we have forged linkages with similar experiments at sites in a nutrient-rich maple forest in Pennsylvania, at the Allegheny College Bousson Environmental Research Reserve (USA) and a temperate coniferous forest at the H. J. Andrews Experimental Forest in Oregon (USA). We hope to develop additional linkages to similar experiments located across climate and soil texture gradients. This will allow an assessment of the importance of physical as well as biological factors in controlling soil organic matter accumulation. Here we present selected results from the first decade of DIRT manipulations at Harvard Forest to illustrate how chronically altering aboveground litter and belowground root inputs to soils can provide useful information about ecosystem processes at short- and long-term timescales.

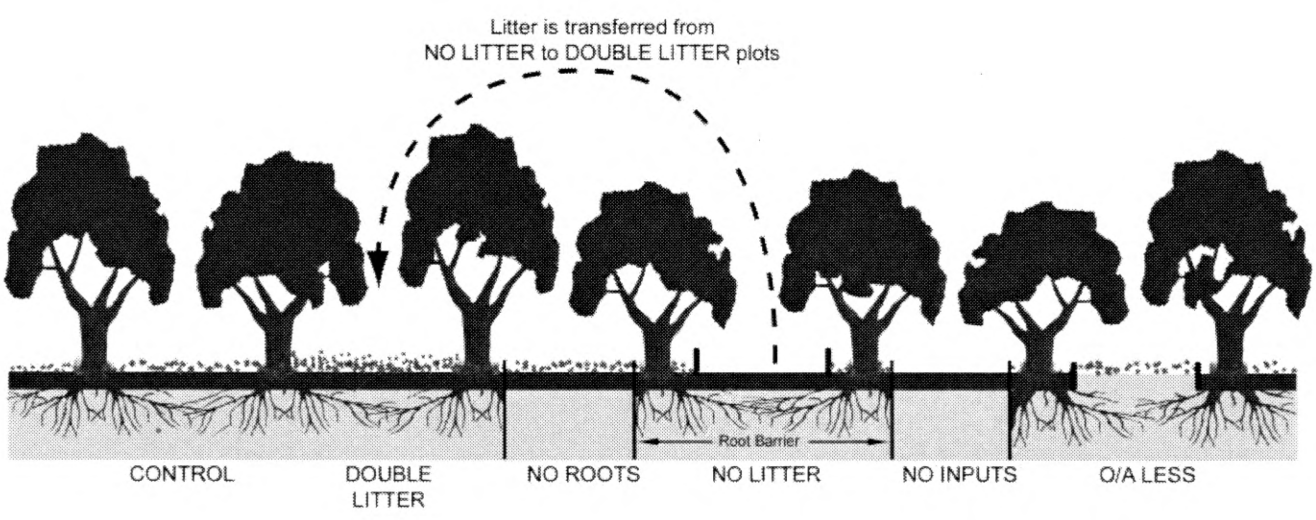

Figure 1. A conceptual diagram of the Detritus Input Removal and Transfer (DIRT) experiment at the Harvard Forest LTER site. The surface organic horizon (Oea) is shown in dark grey. Mineral soils are shown in aggregate in light grey. From Nadelhoffer et al. *in press.*

Although DIRT is addresses processes of soil formation operating at time scales ranging from a single decade to centuries, during the initial years of the study we learned much about processes operating at shorter time scales. Some of these processes include root production, temperature sensitivities of rhizosphere (fine roots and closely associated microbes) respiration versus bulk soil respiration, and shifts in belowground community structure.

Selected Results

We used soil respiration budgets based on measurements done during the second year of treatments to estimate carbon inputs to soils from fine roots (Bowden et al.1993). This analysis suggested that about that yearly C inputs to soils from roots (110 g C ha^{-1} yr^{-1}) at this site were, on average, about equal to C inputs from aboveground litter (138 g C ha^{-1} yr^{-1}). Moreover, CO_2 emissions from the soils due to live root respiration (123 g C ha^{-1} yr^{-1}), root decomposition, and fine litter decomposition were all roughly equivalent.

We found that root+rhizosphere respiration was much more sensitive to seasonal variations in temperature that was bulk soil respiration (Boone et al. 1998). Soil respiration measurements made across growing seasons on plots where roots were allowed to grow (CONTROL, NO LITTER, DOUBLE LITTER) and on plots where root growth was prevented (NO ROOTS, NO INPUTS) showed that Q_{10} values for bulk soils were about 2.4, values for rhizosphere were about 4.6. These findings have important implications for large scale carbon cycling and climate models.

Forest floor structure and function were influenced by treatments as well. For example, C and N concentrations in Oe+Oa horizons (not including fresh litter) had decreased with decreasing inputs after 5 years of treatments (Fig. 2). Treatment related differences in forest floor respiration (Fig. 3) under constant temperature and moisture were even greater than were differences in percents C and N. Information such as this, particularly if collected into the coming decades, will provide valuable information about the proportions of root and leaf litter that are eventually incorporated into soil organic matter (or "humus"). Net N mineralization potentials of forest floor samples incubated in the laboratory also differed according to treatment (Nadelhoffer et al. *accepted*).

Dissolved organic C (DOC) exports from forest floors to mineral soils varied with the amount and source of litter inputs (Aitkenhead and McDowell). By year 7 of manipulations DOC concentrations were significantly higher in the solutions collected from beneath forest floors in DOUBLE LITTER plots and were significantly lower in O/A-LESS plots (also DOUBLE LITTER > CONTROL = NO LITTER = NO ROOTS > NO INPUTS > O/A-LESS). There were no significant differences in DOC concentrations between treatments in the soil solution collected from the mineral horizon, however. Such information can allow us to quantify the importance of forest floor processes in regulating organic matter retention and accumulation in mineral soils.

Soil community measurements that these plots are dominated by fungi rather than by bacteria, particularly in the organic horizons (Fig. 4). Total fungal biomass varied with leaf litter input, with the highest values in DOUBLE LITTER and the lowest in NO LITTER and NO INPUTS plots. The presence of roots, however, appears not to have changed fungal biomass. Forest floor total bacterial biomass appears to have varied inversely with fungal biomass across treatments, except in DOUBLE LITTER in which both fungal and bacterial biomass were high. Active biomass of both fungi and bacteria were remarkably similar across treatments in forest floors. The strong effects of manipulations on mineralization and respiration (above) suggest that the activities of microbial functional types were influenced by treatments Clearly, neither total, nor active bacterial population size is a good predictor of soil processes. Active fungal biomass did not differ among treatments in forest floors. However, was a strong (but non-significant) trend of lower active fungal biomass in DOUBLE LITTER plots.

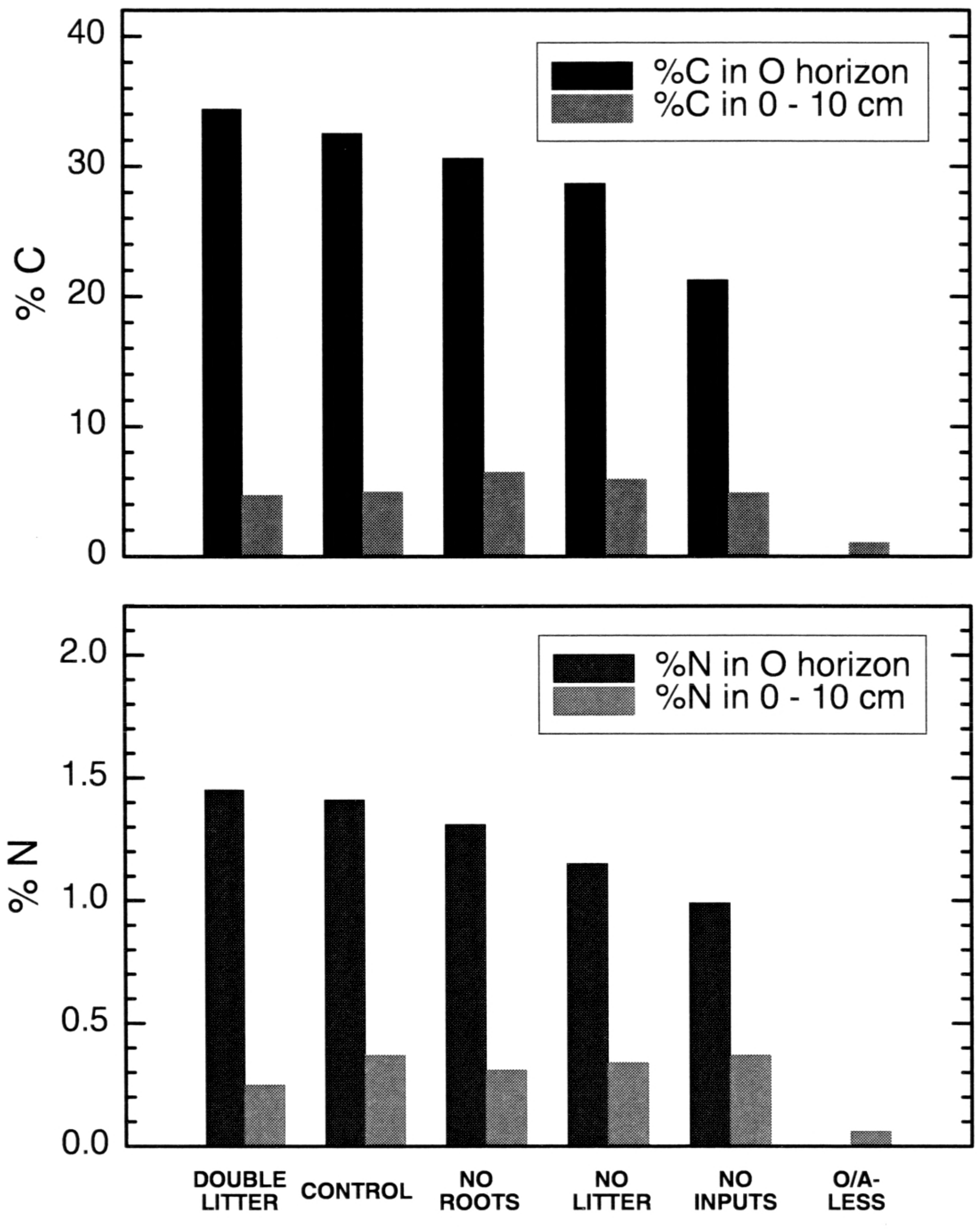

Figure 2. Percents C and N in forest floor (O horizons) and 0-10cm mineral soil after 5 years of litter and root manipulations on the DIRT plots. Bars show means (n = 9). From Nadelhoffer et al. *in press.*

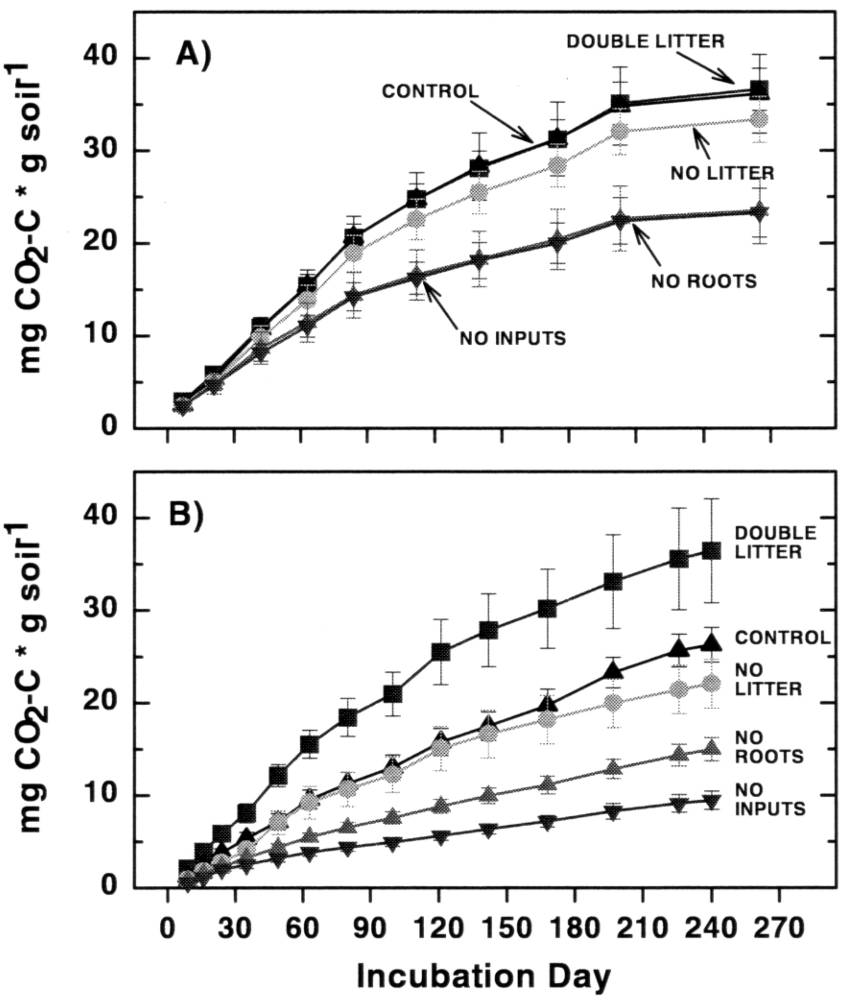

Figure 3. Cumulative respiration of forest floor materials (Oea horizons) collected from the DIRT plots (A) 1 year and (B) 5 years after the start of manipulations in 1990. Samples were incubated at 22 °C and -66 kPa moisture. Symbols show means and standard errors (n = 9).). From Nadelhoffer et al. *in press.*

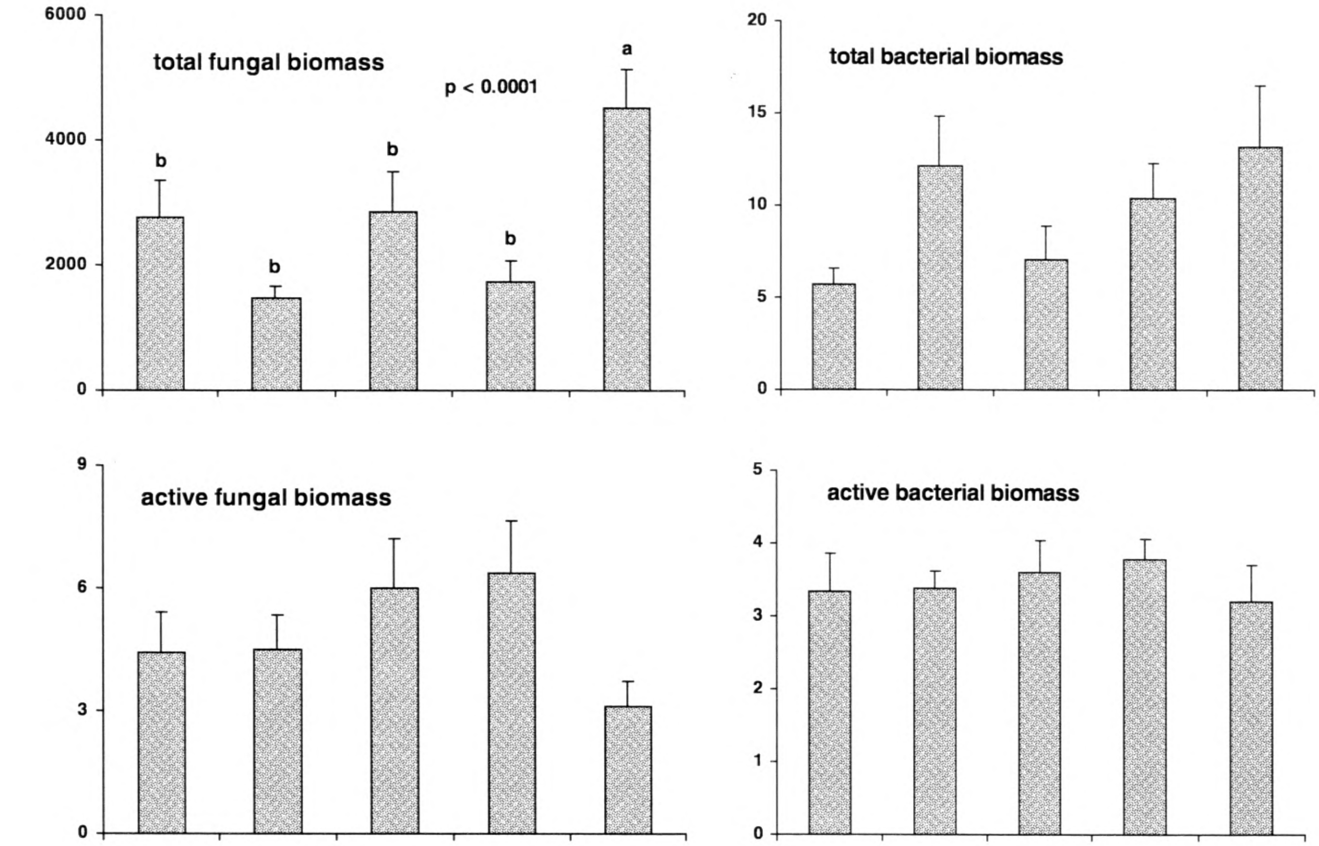

Figure 4. Fungal and Bacterial Biomass in Forest Floors at Year 5 of the Harvard Forest DIRT Manipulations. From Nadelhoffer et al., *in press.*

Summary

Our manipulations of litter and root inputs to forest soils are aimed at [1] quantifying the proportions of aboveground litter and root inputs that become stored as organic matter with long residence times, [2] quantifying how organic matter formation influences soil properties such as nutrient and water retention, and [3] characterizing how the nutrient supplying capacities of soils are influenced by plant litter and root inputs. These goals will require decades of manipulations to be achieved. We have, however, used results from the first years of the experiment to address important questions about forest ecosystem function. Thus, although the overarching goals are long-term, we have exploited the experiment for short-term benefit as well. This is a key to sustaining the interest necessary for justifying the continued maintenance of the plots. Another important feature of long-term experiments is that the manipulations themselves be simple and require a minimum of effort to maintain. This is the case for the DIRT plots, which require several days of activity to remove and add litter annually to subsets of the plots. More effort is required to establish the plots and to re-trench plots from which roots are excluded (every 8 to 12 years).

Measurements thus far indicate that in our temperate deciduous forest site—

- Inputs to soils from roots are approximately equal to aboveground litter inputs.
- Roots + rhizosphere metabolism is more temperature sensitive than is bulk soil respiration.
- Dissolved organic carbon exports from forest floors are about 10 percent of CO_2-C gas losses and are important for driving mineral soil processes.

- Fungal biomass was much greater than bacterial biomass on all plots. However, aboveground litter inputs may be more important substrates for fungi than are roots.
- Effects of above- and belowground inputs on activities microbial functional groups are large, as evidenced by differences in processes among samples from differently treated plots. However, microbial populations are poor predictors of process rates.

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Air Pollution and Forest Health in Central Europe: Lessons from a Regional Network of Sites

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Air Pollution

In Central Europe, and specifically in the former Soviet Block countries, levels of sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) emissions have been steadily declining (Table 1). Initially, reduction of air pollution emissions was caused mainly by the declining industrial activity. However, since the early 1990s, the mechanisms of the free market economy have promoted much more efficient energy use and cleaner technological processes. Polluting industries, such as smelting, mining and chemical manufacturing have been steadily declining. They have been gradually replaced by more competitive industries such as consumer products, automobiles, general manufacturing and service industries (Schnoor *et al.*, 1997). As a result of these changes, the increasing industrial output, which started in Poland in 1991/1992, was accompanied by declining energy use and reduced emissions of dust and SO_2·(Figure 1). Between 1990 and 1994 in the entire region of Central and Eastern Europe, the energy use was reduced by about 20%, accompanied by even higher reductions of industrial emissions (Agren, 1998).

Since 1990, the number of motor vehicles in central and Eastern Europe has drastically risen. In Poland alone, the number of privately owned cars increased from 5.3 million in 1990 to 7.5 million in 1995 (GUS, 1997). It is expected that this trend will continue - at present Poland still has about 2-3 times less privately owned cars per capita than the western European countries or the United States. Increased emissions of nitrogen oxides and non-methane hydrocarbons (NMHCs) from the rapidly increasing number of cars result in increased rate of photochemical smog (including ozone) formation during favorable weather conditions (high solar radiation, high temperatures, and frequent occurrence of stagnant air masses). Elevated ambient concentrations of ozone started to occur in Western Europe already in the 1980s (Dovland, 1987). Presently, high ozone episodes frequently occur in the Mediterranean countries, Switzerland, Germany and Great Britain (Stanners and Bordeau, 1995). Long-range transport of the polluted air masses together with local photochemical processes are likely to result in increasing ozone concentrations in Central Europe, including the Carpathian Mountains. Elevated levels of ozone have already been found in several locations of Poland, the Czech Republic, Slovakia and Ukraine. Maximum concentrations of 14-day averages and 1-hour averages for the selected areas of Central Europe indicate potentially phytotoxic levels of the pollutant (Figure 2).

Table 1. Emissions of sulfur dioxide and nitrogen oxides in selected central European countries (in 1000 tons/year) (after Agren, 1997).

Country	Sulfur dioxide			Nitrogen oxides (as NO_2)		
	1980	1990	1995	1980	1990	1995
Czech Republic	2257	1876	1091	937	742	412
Germany	7514	5326	2995	3334	2460	2210
Hungary	1633	1010	699	273	238	171
Poland	4100	3210	2337	1229	1279	1120
Romania	1055	1311	912	523	546	319
Slovakia	780	543	238	197	227	173
Ukraine	3849	2782	1639	1145	1097	530

Concentrations of nitrogen and sulfur oxides remain high in many areas of Central Europe. This is especially true for the vicinity of major industrial centers, such as the Upper Silesia in Poland or the infamous "Black Triangle" near the borders of Poland, Czech Republic and Germany. However, it has to be emphasized that compared to the situation in 1980s, major improvements in air quality have been accomplished. In the early 1990s, the annual mean SO_2 concentrations in the Silesian Beskid Mountains and the Katowice agglomeration in the Upper Silesia ranged between 30 and 45 $\mu g/m^3$. Such levels are well above 20 $\mu g/m^3$, a value that has been set as a critical level of that pollutant by the UN-Committee for Europe (Godzik *et al.*, 1998). However, such levels are much lower then in 1980 when exceedances of 64 $\mu g/m^3$ were common on the entire territory of southern Poland (Godzik and Sienkiewicz, 1990). Concentrations of NO_2 measured in the Silesian Beskid Mountains and the Katowice agglomeration were between 5 and 10 $\mu g/m^3$, the levels well below the UN-Committee for Europe standard of 30 $\mu g/m^3$ (Godzik *et al.*, 1997). Summer measurements of trace nitrogenous pollutants performed in 1997 in the same locations indicated elevated concentrations of nitric acid (HNO_3) vapor, nitrous acid (HNO_2) vapor, ammonia (NH_3) and particulate nitrate and ammonium (Bytnerowicz et al., 1999). Such elevated concentrations of nitrogenous and sulfurous air pollutants may lead to exceedances of critical loads of nitrogen and sulfur causing acidification and eutrophication in a large portion (43%) of the forested areas in Poland (Sollander, 1999). At the Ratanica site in the foothills of the Carpathian Mountains, the annual depositions of nitrogen and sulfur, were 25 and 26 kg/ha, respectively, in the early 1990s (Grodzinska and Laskowski, 1996).

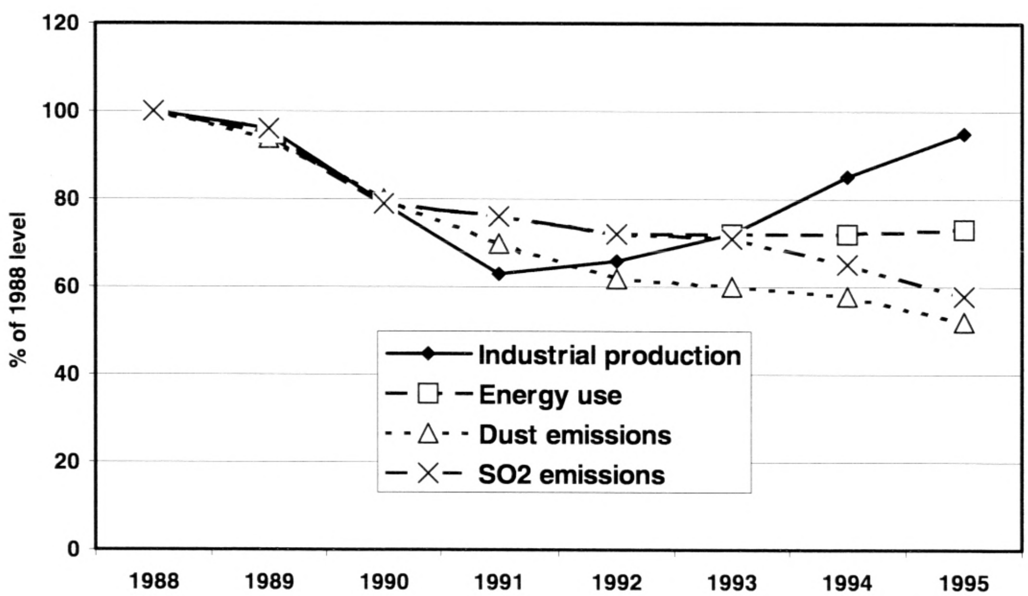

Figure 1. Recent changes in industrial activity, energy use and air pollution emissions in Poland.

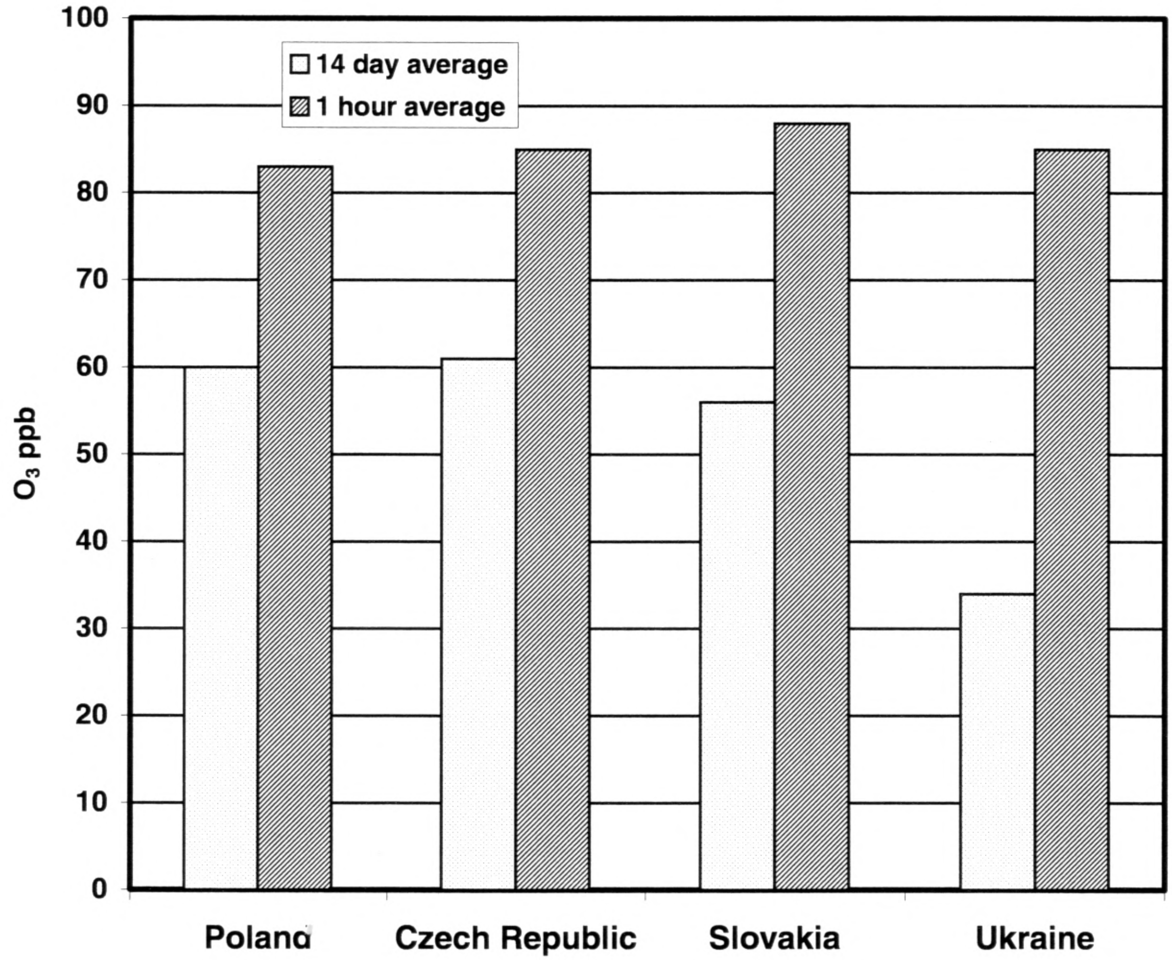

Figure 2. Maximum concentrations of ozone determined in the forested areas in summer 1991 in southern Poland (Bytnerowicz *et al.*, 1993), summer 1994 in the Brdy Mountains, the Czech Republic (Bytnerowicz *et al.*, 1995), summer 1997 in Vyhodna, northern Slovakia (Oszlanyi, personal communication), and in Kiev, Ukraine (Blum *et al.*, 1997).

Health of Forests

Industrial pollution started affecting forests in Central Europe as a result of a rapid development of heavy industry and mining in the second half of the 19^{th} century. After the Second World War, the intensified industrialization and resulting high emissions of sulfur oxides, nitrogen oxides and heavy metals caused extensive forest decline in many areas of Poland, Germany and the Czech Republic (Godzik and Sienkiewicz, 1990, Grodzinska *et al.*, 1990, Bochenek *et al.*, 1997). Although forest condition in many areas of Central Europe has been recently improving, health of forests in the western regions of the Carpathian Mountains, such as the Silesian Beskid in southern Poland, has been worsening (Godzik *et al.*, 1998).

The degree of tree defoliation (crown transparency) may be considered an overall indicator of tree health. Tree defoliation survey levels have become a basis of the large biomonitoring system established in Europe. The UN Economic Commission for Europe and the European Union have coordinated this effort within the ICP-Forests Program. It should be noted that tree defoliation cannot be treated as a specific measure of air pollution effects (Kandler and Innes, 1995). Although air pollution, especially ozone (Miller *et al.*, 1989), may cause increased tree defoliation, other environmental factors such as drought or insect attacks, may also have pronounced effects on foliage loss of trees. Despite various limitations, trends of forest health changes in Central Europe can be adequately described based on the multi-year large scale monitoring of tree defoliation (Busotti and Feretti, 1998). Results of the recent changes in the several countries of Central Europe are presented in Table 2 (Elvilgson, 1997). These data show that despite the recently observed reduction of the industrial pollution emissions, high levels of tree defoliation in the Central European forests continue. Although concentrations of sulfur and nitrogen oxides have been drastically reduced in the area, high levels of nitrogen and sulfur deposition persist and contribute to exceedances of critical loads of these elements on vast areas of central Europe (Elvingson, 1997). High levels of available nitrogen may cause deterioration of growing conditions of trees due to depletion of magnesium, calcium and other essential nutrients in forest soils. Elevated concentrations of ozone may also cause premature needle senescence and increased crown transparency (Miller *et al.*, 1989). It has also been well established that at elevated concentrations ozone is highly phytotoxic and may affect physiological status of plants and reduce their growth (Krupa and Manning, 1988). Ozone may also increase phytotoxic effects of other air pollutants, especially sulfur and nitrogen oxides (Guderian, 1985). Of course, other biotic and abiotic stresses such as pathogens, drought, frost, wind, fire, intensive management practices, etc., may also affect health and sustainability of forests (Oszlanyi, 1997).

Table 2. Results of the national surveys of tree defoliation in selected central European countries presented as percentage of trees in classes 2 - 4 (defoliation >25%) (after Elvingson, 1997).

Country	1990	1991	1992	1993	1994	1995	1996
Czech Republic	47	45	56	52	58	58	72
Germany	-	25	26	24	24	22	20
Hungary	22	20	22	21	22	20	19
Poland	38	45	49	50	55	53	40
Romania	-	10	17	20	21	21	17
Slovakia	42	28	36	38	42	43	34
Ukraine	-	6	16	22	32	30	52

Aside from the effects on trees, elevated concentrations of O_3, SO_2, NO_2 as well as high levels of nitrogen and sulfur deposition may have disastrous consequences for the biodiversity and health of the Carpathian ecosystems similarly to the other already affected European areas (Ashmore et al. 1996, Nihlgard 1985). Protection against the deleterious effects of air pollution should become an essential component of a proper preservation policy for the Carpathian Mountains.

Changes in the Central European forests, especially in the Carpathian Mountains, are complex and not well understood. Due to a very dynamic air pollution status and other factors affecting forests and other ecosystems of the region, long-term, multidisciplinary investigations are urgently needed. Exchange of information and cooperation between scientists and land managers from other areas that experience similar environmental stresses, including the North American forests, are essential for increasing the level of our understanding of the occurring processes and changes. The International Long-Term Ecosystem Research network presently being developed in Central Europe seems to be an ideal setting for providing such opportunities.

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Comparative Watershed Studies - Opportunities and Limitations

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Introduction

The fundamental premise of most small watershed studies is that water quality in streams is intimately linked to biogeochemical processes occurring in the landscape. Early work at the Hubbard Brook Experimental Forest in New Hampshire, USA was the first to formalize this relationship (Bormann and Likens 1967). At Hubbard Brook, experimental manipulations showed that forest dynamics had a large impact on stream water chemistry (Likens et al. 1970) and provided new insights into the nature of linkages between terrestrial and aquatic biogeochemistry. Careful study of elemental dynamics in these small catchments also led to seminal work on acid deposition (Likens and Bormann 1974) and base cation depletion following forest harvesting (Hornbeck and Kropelin 1983). Work at other experimental watersheds (e.g. Coweeta Hydrologic Laboratory, H.J. Andrews Experimental Forest, and the Luquillo Experimental Forest) further demonstrates the value of using a whole-watershed approach to understand processes affecting the chemistry of small streams and rivers.

In this paper, I address three aspects of small watershed studies relevant to efforts of the ILTER to foster such work in Eastern Europe. They are: 1) experimental designs used in small watershed studies; 2) the variety of spatial scales at which small watershed studies can be undertaken; and 3) research opportunities particularly appropriate for Central and Eastern Europe. For each topic, I will address both opportunities provided by small watershed studies, and their limitations.

Experimental Design

Experimental design is a crucial aspect of any environmental study. Typically, experimental designs in small watershed studies are limited by the availability of sufficient time and money to conduct the project, or physical limitations of the test watersheds. In particular, it is often is very difficult to find “replicate” watersheds in a region. This makes the use of classic experimental designs, such as a randomized block design, especially difficult. Despite these problems, it is nonetheless instructive to consider the various experimental designs commonly used in small watershed studies.

Many small watershed studies are best described as post-hoc comparisons (Figure 1). Typically, a difference between two watersheds in some characteristic such as levels of atmospheric deposition or bedrock chemistry is measured, and the chemistry of stream water is compared between the two sites. Conclusions are then drawn, for example, about the effect of atmospheric deposition on stream chemistry. A good example of such a study is provided by Driscoll et al. (1988), who examined the likely effects of atmospheric deposition on stream chemistry by comparing results from Hubbard Brook and British Columbia. The principal limitation of the post hoc comparison is that it is often difficult to sort out the effects of other differences in the study watersheds that might have contributed to the observed differences in stream chemistry.

Another commonly used experimental design is the before-after comparison. The principal feature of this design is that two sites are compared both before and after a disturbance or experimental treatment. This experimental design is typically used to determine the impact of some catastrophic natural or anthropogenic disturbance. Good examples of a before-after design include classic studies on the impacts of deforestation at Hubbard Brook (Likens et al. 1970) and studies of the impacts of hurricane-driven deforestation on groundwater chemistry (McDowell et al. 1996).

The before-after comparison is a more powerful design than the post-hoc comparison, because it does not assume that the two watersheds were similar prior to the disturbance event. It only assumes that the relationship between the two watersheds would have remained unchanged were it not for the disturbance. This design is particularly appropriate where long-term changes in stream chemistry are occurring, or seasonal changes occur, as it can control for them.

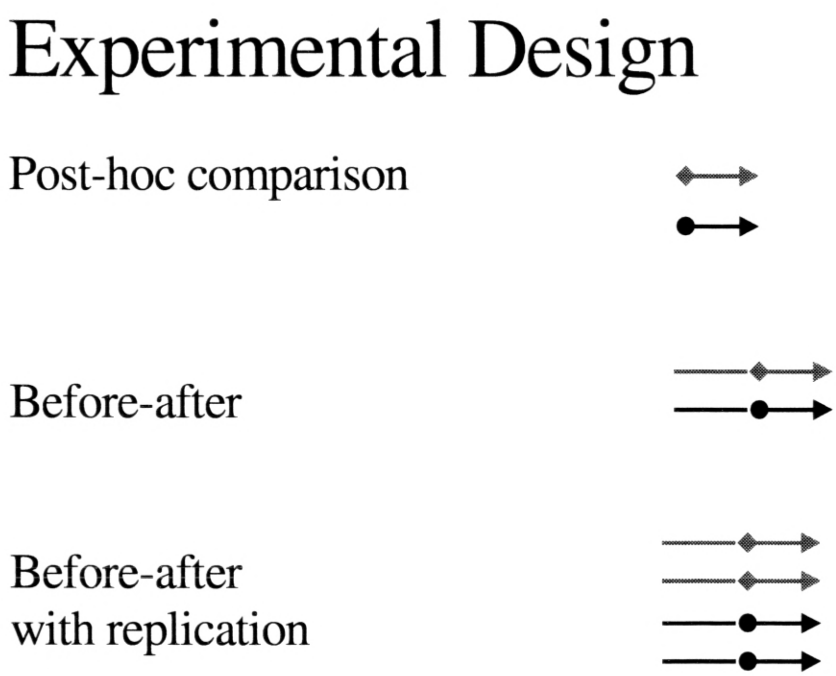

Figure 1. Features of three experimental designs commonly used in watershed studies. Arrows indicate the period of study; symbols (circle or diamond) indicate the time at which an experimental manipulation was conducted. Circles represent "reference" watersheds; diamonds indicate "experimental" watersheds.

A third experimental design is the before-after comparison with replication. This is the most powerful design, because it adds replication to watershed studies and thus increases the power of any statistical analysis of the results. Replication provides obvious benefits in strengthening the investigator's conclusions, but also has obvious costs, and these costs are often prohibitive. At Hubbard Brook, for example, there have never been any replicated watershed experiments. This has been due to the costs of conducting replicated experiments, and the limited availability of watersheds for experimental manipulations. An alternate approach to true replication is to complete a second manipulation which largely duplicates the first but adds some subtle differences in experimental treatment. At Hubbard Brook, the original whole-watershed manipulation (felling tees and leaving them in place; Likens et al. 1970) was followed by a whole-tree harvest which removed all of the above-ground biomass (Lawrence and Driscoll 1988).

Spatial Scale

In addition to experimental design, another important consideration in small watershed studies is the spatial scale at which the studies are conducted. Watershed studies can be conducted at multiple spatial scales, each with strengths and weaknesses. In this section, I will describe the results of some of my work at the local, landscape, regional, and global scales.

Local By "local" scale, I mean the study of several watersheds in close proximity to each other. The underlying premise of most watershed studies conducted at the local scale is that differences in a few salient characteristics (e.g. bedrock geology, disturbance regime, etc.) can be used to determine the effects of that characteristic on nutrient losses in drainage waters. A recent study of elemental losses from two watersheds at the Caribou-Poker Creeks Research Watershed (MacLean et al. 1999) exemplifies this sort of approach. Two watersheds were chosen from the experimental watersheds at this LTER site, one north-facing (with high permafrost) and a second south-facing (with low permafrost). Nutrient export was measured for a year, and differences between the two watersheds were ascribed to differences in hydrologic flow paths and vegetation associated with differences in permafrost cover. The study design was a post-hoc comparison without replication (Fig. 1). Results of the study were particularly dramatic for dissolved organic carbon. DOC losses were much higher in the permafrost-dominated watershed, although losses of nitrate and dissolved organic nitrogen (DON) were similar (MacLean et al. 1999). From these results, the authors concluded that changes in DOC export were likely to result from even modest changes in permafrost coverage due to climate change.

Landscape By "landscape" scale, I mean studies of a number of watersheds in relatively close geographic proximity that vary in a combination of characteristics such as elevation, rainfall, vegetation, and soils. Studies at the landscape scale provide insight into the variation in nutrient losses associated with local differences in environmental factors. An example of such a study is given in Schaefer et al. (in press), who examined the response of 8 different watersheds in the Luquillo Mountains in Puerto Rico to the passage of Hurricane Hugo in 1989 as part of the Luquillo LTER. The experimental design was before-after with multiple replicates (Fig. 1) but no true reference watersheds, as all of those studied suffered considerable damage from the hurricane. In the first year following the hurricane, average losses of K^+ and NO_3^-, respectively, were double and triple pre-hurricane values. Their results showed that variation among watersheds was considerable, with little increase in annual nutrient losses from some watersheds and large increases in others. Differences in the magnitude of hurricane damage presumably were responsible for the differences in biogeochemical responses among watersheds, but experimental manipulations would be required to verify this conclusion.

Table 1. Export of dissolved organic carbon, dissolved organic nitrogen, and nitrate (kg ha^{-1} yr^{-1}) from two watersheds in the Caribou-Poker Creeks Research Watershed, Bonanza Creek LTER. HiP=watershed C3, with high permafrost coverage; LoP = watershed C2, with low permafrost coverage. Data from MacLean et al. 1999.

Watershed	DOC	DON	NO_3-N
HiP	6.45	0.71	0.13
LoP	2.31	0.68	0.15

Regional Understanding and predicting variation in nutrient losses among small watersheds has long been an objective of ecosystem ecology (e.g. Vitousek and Reiners 1975, Hedin et al. 1995). Within a given region, variation in land use, site history, or bedrock is most likely to affect stream export. Results from McDowell et al. (1995) show the likely importance of land use in regulating N loss from tropical watersheds. They found that among watersheds draining Caribbean islands, human population density was a good predictor of N losses, while P losses were inversely related to population density and seemed to be most closely linked to soil age (Fig. 2). This study is another example of a post-hoc comparison, as no data were available for watershed export before extensive human modification of the watersheds.

Global In the coming decades, developing predictive models that describe the response of watershed fluxes of carbon and nutrients to climatic changes will take on increasing urgency. Accurate global models require an understanding of the factors driving variation in nutrient losses across biomes. Recent work by Aitkenhead and McDowell (in press) provides an example of one such model. By comparing DOC fluxes and soil C/N ratios among biomes, they found that soil C/N is an excellent predictor of DOC flux (Figure 3). The nature of the relationship between soil C/N and riverine DOC flux is unclear at present. Reconciling this relationship with previous observations made at local and regional scales (e.g. Eckhardt and Moore 1990; Hope et al. 1997) is likely to force a re-assessment of the factors controlling DOC production and flux in various biomes. Based on our results, we believe that biotic processes regulating DOC production (as reflected in soil C/N) may be more important in controlling DOC losses than previously suspected.

Limitations of past watershed studies

Few research networks have successfully completed comparative watershed studies at a regional or larger scale, and the US LTER network is no exception. Successful studies have been completed at the local and landscape scale, but no network-wide watershed studies have been undertaken. This is due primarily to the fact that the LTER network was established as a series of sites addressing common themes with unique, site-specific approaches. Coordinated studies across the network were encouraged, but not required. Several studies have been undertaken in recent years at multiple sites, including LIDET (a study of terrestrial litter decomposition; Moorhead et al. 1999), and LINX, which addresses nitrogen cycling in streams (Mulholland et al. in press), but neither focuses on small watersheds as a unit of study. The lack of comparative watershed studies in the LTER system results more from a lack of funding and vision than from any inherent limitations in the comparative, whole-watershed approach to addressing questions in ecosystem ecology.

Opportunities in Central/Eastern Europe

I see a variety of research opportunities in Eastern and Central Europe for which a comparative watershed approach would be most appropriate. They include the following:

- To what extent are watersheds with varying deposition regimes "saturated" with respect to nitrogen?
- Are there measurable differences in watershed N pools associated with differences in current and historic N deposition rates?
- Can elemental losses (e.g. K^+, Ca^{2+}) be used as indicators of ecosystem health?

In selecting a focus for future study, careful attention should be paid to the global context in which the studies are undertaken. Highest priority should be given to two categories of research: projects which have a compelling local interest, and those for which projects in Central/Eastern Europe provide a valuable end member along some sort of gradient. The most obvious example of this is atmospheric deposition, because high levels of acidic deposition in parts of the region provide globally significant research opportunities.

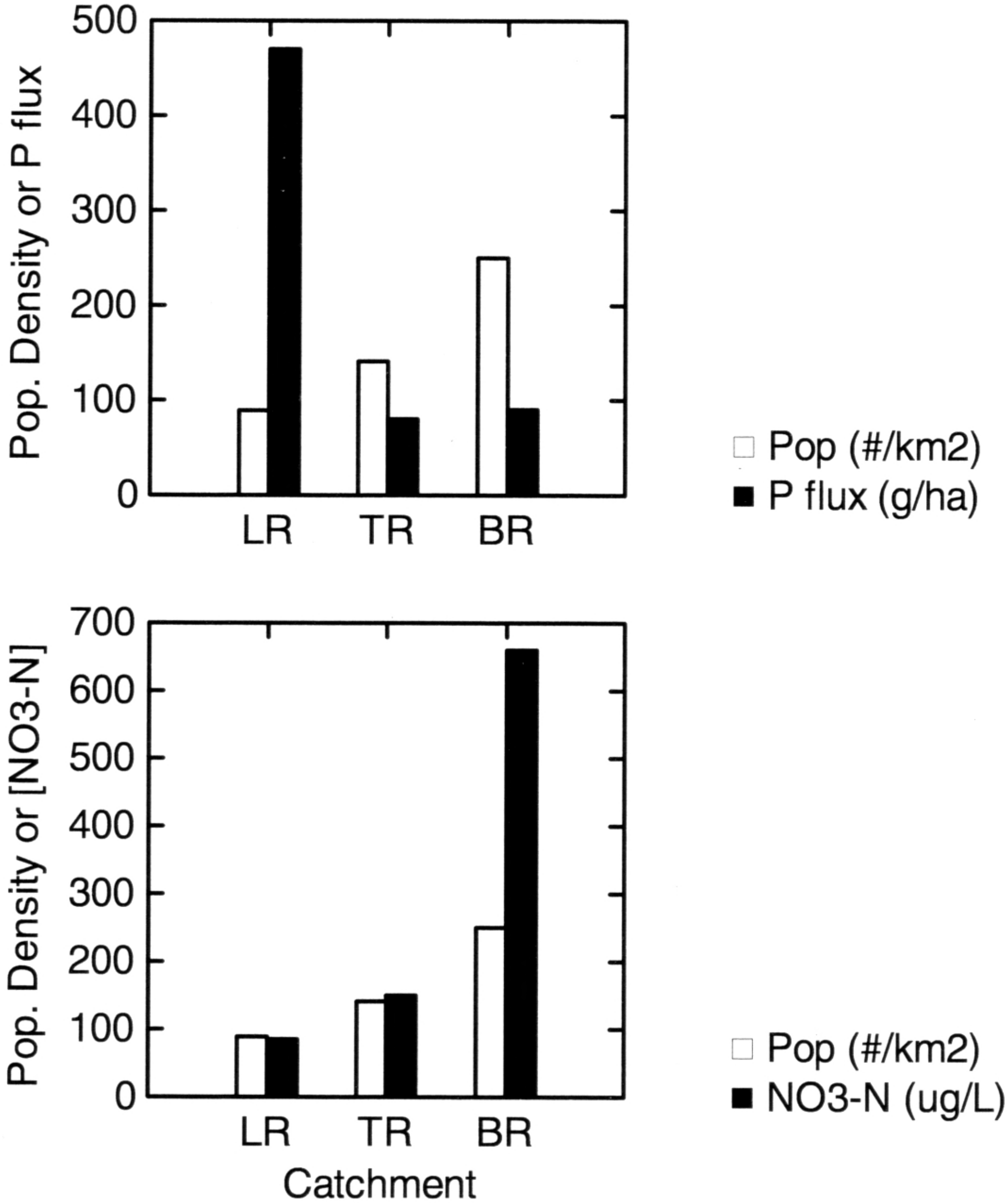

Figure 2. Population density and export of total P (upper panel) and concentration of nitrate-N (lower panel) for three Caribbean watersheds. LR=Layou River, Dominica; TR=Troumassee River, St. Lucia. BR = Buccament River, St. Vincent. Data from McDowell et al. 1995.

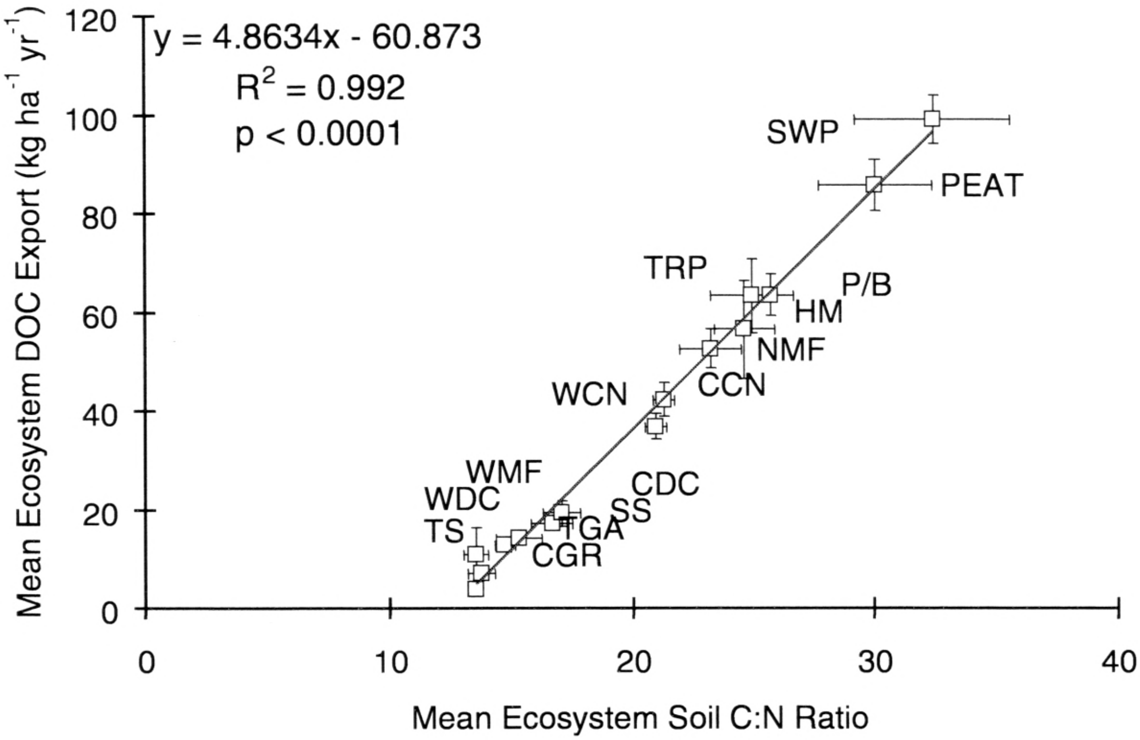

Figure 3. Mean (± SE) annual riverine DOC flux as a function of mean (± SE) soil C:N for fourteen biome types. CGR-cool grasslands; TS-tropical savanna; TGA-taiga; SS-Siberian steppe; WDC-warm deciduous forests; WMF-warm mixed forests; CDC-cool deciduous forests; WCN-warm conifer forests; CCN-cool conifer forests; NMF-northern mixed forests; HM-heath moorland; TRP-tropical forests; P/B-peat/boreal mix; PEAT-peatlands; SWP-swamp forests. From Aitkenhead and McDowell (in press).

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Development of a Forest ILTER in Central Europe

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Introduction

During the Regional ILTER Workshop hosted by the Institute of Ecology and Botany of the Hungarian Academy of Sciences in Budapest on 22-25 June 1999, a group of European and U.S. scientists discussed research needs for the long-term ecological research in forests of Central Europe.

The group consisted of: Per Gundersen (Denmark), Imre Berki, Attila Borhidi, Ilona Meszaros, Janos Attila Toth, Bela Tothmeresz (Hungary); Krystyna Grodzinska (Poland); Ion Barbu, Dan Cogalniceanu (Romania); Pavol Elias, Peter Fleischer, Lubos Halada, Blanka Mankovska, Denisa Popierova (Slovakia); Ihor Kozak (Ukraine); Andrzej Bytnerowicz (*Chair*), Kate Lajtha, William McDowell, Knute Nadelhoffer, Kristin Vanderbilt (*Rapporteur*), (United States).

Selection of sites for the ILTER forestry research

Prior to the Budapest meeting, as a result of their early involvement in planning stages of the ILTER network in Central Europe, the Czech Republic, Hungary and Poland have officially selected and approved their first ILTER forest sites for the Region. These are:

Czech Republic - the Krkonose Mountains, the Sumava Mountains, Krivoklatsko and the Bile Karpaty Mountains (Waide et al., 1998; Straskrabova and Flousek, 1999)

Hungary - the Sikfokut oak forest and the Kinkunsag forest-steppe ecosystem (Waide et al., 1998; O'Heix and Toth, 1999)

Poland - the Bialowieza, Bieszczady and Kampinos National Parks (Waide et al., 1998; Perzanowski and Prus, 1999).

Other forested areas have been discussed as potential ILTER forest sites at the workshop in September 1998 held in Madralin near Warsaw, Poland. These were listed in the proceedings from that meeting:

Poland - the Niepolomice Primeval Forest and the Tatra National Park (Perzanowski and Prus, 1999)

Romania - the Retezat and Pietrosul Rodnei Biosphere Reserves in Romania (Vadineanu, 1999)

Ukraine – the Carpathian National Park/Biosphere Reserve (including the Chornohora range) and the Beskydy area (including the Stuzhitsa range of the trilateral Eastern Carpathian Biosphere Reserve and forests of the Starosambirskij district) were listed as the primary candidates for the forest ILTER sites. Description of these sites was provided in the proceedings of the ILTER meeting (Kozak, 1999). The Carpathian National Park/Biosphere Reserve and the Beskydy area have been officially endorsed by the Ukrainian National Academy of Sciences (Ihor Kozak, personal communication). In addition, the Synevir, Vyzhnytsya, Podilsky Tovtry, Shatskij and Svyati Hory National Parks as well as the Horhany and Polyssian Nature Reserves are considered as potential ILTER sites (Akimov, 1999).

During discussions at the Budapest meeting, the Slovak delegation listed the Tatra, Lower Tatras, and Poloniny National Parks as well as the Polana and Bab Biosphere Reserves as potential sites included in the network of forest ILTER. For Romania, the Retezat, Piatra Craiului-Bucegi, Rodna, and Rarau Mountains were listed as additional potential sites. For Hungary, the Regtek beech forests were mentioned as a new potential research site.

On September 23, 1999, the above forest sites proposed as candidates for the ILTER cooperation in Romania have been officially approved by Mr. Anton Vlad, the Minister of Waters, Forest and Environmental Protection.

On October 1, 1999, the Slovak Academy of Sciences approved the Eastern Carpathian and Tatra National Parks and the Polana and Slovak Karst Biosphere Reserves as official sites for the ILTER network.

Research problems related to air pollution and other stresses in Central European forests

Industrial and agricultural activities in densely populated Central Europe have caused serious ecosystem changes due to eutrophication and acidification. However, since the early 1990s, agricultural and industrial activities have been reduced because of the political and the subsequent economic changes. Reduced levels of S and N pollution, decreased use of fertilizers, and increasing area of abandoned agricultural land are the most recent factors affecting ecosystem changes (Weide *et al.*, 1998). Dynamic growth of number of automobiles causes increasing potential for ozone production and far reaching changes in the air pollution status of this part of Europe (see Bytnerowicz, this volume). Various abiotic and biotic stresses, especially air pollution, periodic droughts, outbreaks of insect infestations, as well as improper land management practices affect sustainability and health of forest ecosystems. Potential implications include increased defoliation of trees and changes in nutrient status caused by long-term deposition of nitrogenous air pollutants and altered dynamics of forest growth. These changes may affect also carbon dioxide acquisition and carbon budgets of forests and other ecosystems. Changing environmental conditions also affect diversity of forest flora and fauna. Quality of ground and stream water in forest watersheds is another important issue with major implications for people of Central Europe.

Specific research ideas discussed at the Budapest meeting:

a. How do changes in forests of the Carpathian range compare with forests in other parts of Europe, namely in the forests of the NITREX research network? In particular, how do air pollution (nitrogen deposition and ozone) and other factors (different soils and type of forests) affect carbon and nitrogen status of forests?

Changes in C/N, DIN, DON, DOC in KCl soil extracts may provide a good index of availability of nutrients, including N and C. Simplicity of the method would allow performing such measurements in a relatively dense network of sites (Per Gundersen, personal communication).

An establishment of a network of small catchments in the Carpathian Mountains was suggested. Such a network would allow for studying pollution deposition, cycling and forest responses to air pollution and management practices (including comparison of changes in managed vs. natural forests). Inputs vs. outputs of nutrients as affected by atmospheric deposition could be measured. Responses of forests in granite vs. limestone catchments could be determined. Understanding of differences in the input/output budgets could be explained by characterization of forest floor chemistry, ^{15}N soil profiles, and indices of forest health across a range of forest sites (Bill McDowell and Kate Lajtha, personal communication). Experiences of the NITREX are valuable in planning a research program in the Carpathian Mountains. The scientists involved in the ILTER research in Central Europe can greatly benefit from close cooperation with the NITREX researchers.

Presently, in the Romanian Carpathian Mountains, deposition of S ranges between 8 and 18 kg/ha/yr compared with 15 and 40 kg/ha/yr in 1985. Present deposition of N ranges between 20 and 26 kg/ha/yr for most of the range, but at some locations such as in the Bucegi N deposition of about 8 kg/ha/yr may be expected. Present deposition of N and S in the Hungarian forests is about 20 kg N/ha/yr and about 20 kg S/ha/yr. Information on C/N ratios and other soil characteristics in Romanian forests has been extensively gathered since the 1960s and is readily available (Ion Barbu, personal communication). Also in Slovakia, information on C/N ratios in mineral soils is available since the 1960s. As an example, there are 100 sites in the High Tatra Mountains where such measurements have been performed (Peter Fleischer, personal communication).

Knute Nadelhoffer and Kate Lajtha suggested that collaboration would be established between the Detritus Removal Treatment Study (DIRT) and some of the Central European forest sites. Litter decomposition is an important indicator of N status in forest ecosystems and can be studied on the NS transect network of intensive research sites (see Scandinavian sponsored studies in Central and Eastern Europe). Scientists of the Sikfukut Project in Hungary are interested in pursuing such collaborative research. Biogeochemical studies, especially on a relatively dense network of sites will require substantial financial support. Therefore new research proposals will have to be developed and submitted to potential European and U.S. sponsors.

b. How do air pollution and other stresses affect biodiversity of the Carpathian forests?

Biodiversity changes are currently studied on vegetation plots in the selected sites of the Carpathian Mountains within the ozone/biodiversity studies sponsored by the USDA Foreign Agricultural Services. In addition, at those sites growth of trees is measured by the analysis of annual growth increments of trees (tree cores) and effects of bark beetles on forest health is evaluated.

Current studies of air pollution effects in the Carpathian Mountains

Currently two projects are conducted as a collaborative effort of the Czech Republic, Poland, Romania, Slovakia, Ukraine and the United States: Project No. 1 "Evaluation of Ozone Air Pollution and Its Phytotoxic Potential in the Carpathian Forests", and Project No. 2 "Effects of Forest Health on Biodiversity with Emphasis on Air Pollution in the Carpathian Mountains". These studies are supported by the USDA Foreign Agricultural Services with an additional support from the USDA Forest Service International Forestry, International Union of Forest Research Organizations (IUFRO) and the participating European research institutions (Bytnerowicz et al., 1999).

As a result of these two studies, a monitoring network for ozone, sulfur dioxide and nitrogen dioxide concentrations has been established in the Carpathian Mountains. Spatial and temporal maps of air pollution in conjunction with reliable and systematic forest health evaluation will provide a scientific basis for better understanding of causes of the continuing forest decline in the Carpathian Mountains. The established network will provide valuable information needed for understanding mechanisms of forest ecosystem changes related to air pollution and other anthropogenic stresses.

New forest sites for the Central European ILTER network

a. prospective sites sponsored by the USDA

The Tatra, the Eastern Carpathian and the Retezat Biosphere Reserves represent highest ecological and cultural values for the Carpathian Mountains. All these locations are on a list of the UNESCO Man & Biosphere Reserves and have also a status of national parks. These reserves have been included in a research proposal recently submitted to the USDA Forest Service International Forestry/USDA Foreign Agricultural Services. These three areas would become the first ones in a planned more extensive ILTER network of forest sites in Central Europe.

Air pollution is a potential problem for the entire Carpathian Mountain range. The air pollutants may have direct effects on health of forests, biodiversity and ecosystem processes. They may also have indirect effects on forests and other ecosystems, such as promotion of secondary stresses, such as bark beetle infestations or toxicity of heavy metals in soils. Changes in pollution composition, and spatial and temporal distribution are dynamic due to changing climate and human activities. Therefore, monitoring of air pollutants and their effects has been designed as a long-term activity.

The Tatra Bilateral Biosphere Reserve is located on both sides of a border between Poland and Slovakia. In 1992, the Tatra Mountains were included into the UNESCO MAB reserve system. The Reserve has a total area of 145,600 ha, with about 1/3 of this territory as a core are representing all of the most valuable and representative for the Tatra ecosystems. The Tatra Mountains is the highest mountain range of the northern Carpathian Mountains (with some peaks exceeding 2,600 m elevation). The High Tatra Mountains are built of the crystalline rocks, while the Western Tatra Mountains of both crystalline and sedimentary rocks. The most eastern part of the Tatra BR, the Bielanske

Tatra Mountains, are built of limestone. The Tatra Mountains have strongly diversified flora and fauna distributed between the forest and alpine zones. The lower forest zone (up to about 1,250 m) consists of beech (*Fagus silvatica*) and fir (*Abies alba*) forests on the calcium carbonate-rich soils, while Norway spruce (*Picea abies*) forests are dominant on granitic soils. In the upper forest zone (1,250 – 1,550 m), the spruce forests are dominant. The upper forest transition zone has an admixture of stone pine (*Pinus cembra*). In this zone rich flora occurs, and is represented by primrose (*Primula auricula)*, edelweiss (*Leontopodium alpinum*), gentian (*Gentiana clusii*), carnation (*Dianthus praecox*) or alpine aster (*Aster alpinus*). The dwarf pine (*Pinus mugo)* zone stretches between 1,500 and 1,600 m. On granitic soils, dwarf pine is accompanied by other shrubs, such as *Sorbus aucuparia*, *Rosa pendulina*, and *Salix silesiaca*, and on limestone by *Sorbus aria*. Above the dwarf pine zone, high mountain grasslad zone occures. At this zone, on granitic rocks, the primary species are *Juncus trifudus* and *Oreochloa disticha* mixed with low fescue (*Festuca supina)*, campanula (*Campanula alpina*), pasqueflower (*Pulsatilla alba*) and others. On limestone, shrubs such as mountains avens (*Dryas octopelata*) and willow (*Salix reticulata)* with other species such cyclamen (*Viola alpina*) and crowfoot (*Ranunculus thora*) grow. On the highest granite peaks, in extremely difficult conditions, about 120 species of flowering plants and pteridophydes occur. The fauna is richly represented, with such rare animals like chamois (*Rucicarpa rucicarpa*), brown bear (*Ursun arctos*), or marmot (*Marmota marmota*). The vegetation zonation, the varied forms of adaptation of plants and animals to life in high mountain conditions, and the occurrence of rare and endangered species, often endemic for the area, make these mountains very attractive to tourists and scientists (Krzan *et al*., 1996). Recently, the Tatra Mountains have experienced severe anthropogenic pressure caused mainly by extensive tourist activities, rapid development of urban infrastructure in the immediate vicinity of the Reserve, grazing, and air pollution originating from the local and remote sources. Losses of floral and faunal biodiversity as well as deteriorating health of the spruce forests are among major ecological concerns for the Tatra Mountains (Peter Fleischer, personal communication). The Tatra Mountains, due to their high ecological value for Poland and Slovakia, have a long history of ecological research with rich data sets.

An overall objective for the Tatra research is to understand air pollution distribution and effects on biodiversity and health of managed and natural forests. Specific objectives include: (a) characterizing spatial and temporal distribution of ozone, sulfur dioxide, ammonia and nitrogen dioxide; (b) evaluation of incidence and severity of air pollution injury to vegetation; (c) selection of native indicators of air pollutants with a special emphasis on ozone; (d) evaluation of effects of ozone and other pollutants on forest health and biodiversity in managed and natural spruce forests; (e) evaluation of responses of bark beetle populations to disturbance interactions related to environmental stresses, especially air pollution; (f) comparison of genetic diversity in managed and natural Norway spruce forests.

The Retezat Biosphere Reserve is located in Romania in the southern Carpathian Mountains. The Retezat Reserve has been proposed to become a model for conservation efforts in Romania and other countries. This effort has been supported by the World Bank and is included into its Global Environment Facility (GEF) network. The Reserve covers 80,000 ha and is the highest range of the southern Carpathians with 19 peaks exceeding 2,000-m elevation. These mountains are characterized by rich flora represented by 1,186 species, 104 sub-species and 312 varieties). The fauna is also rich and includes such endangered species as chamois, bear, lynx, or wolf. Since 1990, grazing of alpine areas has become the major threat to biodiversity of the Retezat Mountains. Current pressure from grazing is endangering sustainability of the biological resources of these mountains.

An overall objective for the Retezat research is to characterize air pollution distribution and its potential effects on vegetation diversity. Specific objectives are:

(a) characterization of spatial and temporal distribution of ozone, sulfur dioxide, ammonia and nitrogen dioxide;

(b) evaluation of incidence and severity of air pollution injury to vegetation;

(c) selection of native indicators of air pollutants with a special emphasis on ozone;

(d) evaluation of effects of ozone and other pollutants on forest health and biodiversity;

(e) evaluation of effects of various land management practices on mountain ecosystems.

The Eastern Carpathian International Biosphere Reserve covers 154,000 ha near the borders between Poland, Slovakia and Ukraine. In November 1992, UNESCO officially approved the Polish-Slovak MAB Reserve. In 1999, the final acceptance of the Trinational Man and Biosphere Reserve with full participation of Poland, Slovakia and Ukraine was accomplished. In Poland, the Reserve includes the Bieszczady National Park, in Slovakia the Poloniny

National Park, and in the Ukraine, the Stuzhitsa Reserve. Additional buffer areas have been added to the Reserve. The Eastern Carpathians represent the most pristine and most scarcely populated range within the entire Carpathian Mountains. The vegetation is characterized by a specific elevational zonation. Unlike in the Western Carpathians, there are only three elevational ecological zones: the foothills (up to 500 m), the lower forest zone (500 - 1150 m), and the mountain meadows zone (above 1150 m). Spruce forest zone characteristic of the upper forest zone and the zone of dwarf mountain pine are not present. It is believed that the dwarf mountain pine zone is replaced by groves of alder (*Alnus viridis*), which is a botanical phenomenon unique for this region. On the territory of the Polish Bieszczady National Park, 31 plant communities have been described, including 10 forest and shrub associations. Old beech forests and mountain meadows (poloniny) are unique for the European mountains and of a special ecological value. In the forest zone, the dominant tree species are fir, beech and sycomore (*Acer pseudoplatanus*). Some of the typical understory species are *Lunaria rediviva*, *Allium ursinum*, *Festuca drymeja* or *Carex pilosa*. About 900 vascular plants, 250 species of mosses and 300 species of lichens, and a rich variety of fungi occur in the Reserve. Some of the important plants are: the pink (*Dianthus compactus*), vipers grass (*Scorzonera rosea*), violet (*Viola dacica*), cornflower (*Centaurea kotschyana*), veratrum (*Veratrum album*) or hellebore (*Helleborus purpurascens*). Among 56 protected species, the moist interesting are monkshoot specues (*Aconitum tauricum* and *A. paniculatum*), gentian (*Gentiana cruciata*), ostrich fern (*Metteucia struthiopteris*), round-leved sundew (*Drosera rotundifolia*), and marsh helleborine (*Epipactis palustris*). Among the animals, brown bear, European bison (*Bison bonasus*), lynx (*Lynx lynx*), wildcat (*Felis silvestris*), wolf (*Canis lupus*), wild boar (*Sus scrofa*) and red deer (*Cervus elaphus*) are found (Denisiuk et al., 1996). Due to different management and nature protection practices in Poland and Ukraine after the World War II, interesting differences in responses of natural ecosystems have developed on two sides of the border (Perzanowski, 1999).

An overall objective of research in the Eastern Carpathian Reserve is to characterize changes of differently managed ecosystems to anthropogenic influences with a special emphasis on air pollution. Specific objectives are:
(a) characterization of spatial and temporal distribution of ozone, sulfur dioxide, ammonia and nitrogen dioxide;
(b) evaluation of incidence and severity of air pollution injury to vegetation;
(c) selection of native indicators of air pollutants with a special emphasis on ozone;
(d) evaluation of effects of different management practices on forests and mountain meadow ecosystems including changes in their biodiversity;
(e) evaluation of the genetic diversity of natural spruce forests.

A similar approach will be applied for large portions of the proposed research in three locations. The main emphasis of the proposed studies is to establish a good understanding of air pollution distribution and its potential for toxic effects on vegetation. Therefore, some of the objectives are identical for all the areas. Additional specific objectives reflect unique research questions asked for each individual area. Since the most severe changes in forests and other ecosystems have occurred in the Tatra Mountains, this Biosphere Reserve is the primary target area. A widely spread dieback of Norway spruce forests in the Tatra Mountains is a very serious ecological and management problem. On the other hand, effects of land management and other human activities on relatively pristine ecosystems of the Eastern Carpathian and the Retezat Biosphere Reserves are also of high importance. Our research, due to its multidisciplinary approach, will help to understand causes of the observed changes. Results from the current studies sponsored by the USDA ICD (see above) will provide background information valuable for long-term comparison of air pollution distribution trends in the three study sites and the entire Carpathian Mountains range.

b. other candidate sites:

<u>Romania</u>

Piatra Craiului and Bucegi – these two adjacent mountain ranges cover about 100,000 ha and are located in south-central Carpathian Mountains. They have been proposed as a Natural Park funded partially by the World Bark through its GEF projects. The Piatra Craiului and Bucegi Mountains contain about 3,400 ha of pristine mixed and conifer forests and alpine ecosystems surounded by managed forests. Piatra Craiului Mountains consist mostly of limestone. The north-west part of Piatra Craiului has numerous valleys and the eastern ridge is a rich karst area with many caves. The entire area of the Piatra Craiului range has been protected since 1939. The area has the highest concentration of brown bear, wolf and lynx for Europe and many other protected and endangered species of fauna and flora (Wielochowski, 1998). The Bucegi Mountains consist of limestone and crystalline rocks. The mountains are characterized by a high diversity of plants and animals - more than 30 types of forest communities with many species of endemic plants have been identified. The Bucegi Mountains are under a strong anthropogenic pressure, especially in the low forest range and in the alpine meadow zone. The first experimental forest station for the Bucegi Mountains was established in Sinaia in 1930. Long-term forest treatment experiments have been conducted and long-term research in the areas of geology-geomorphology, botany, soil sciences, forest ecology, entomology and lichenology have been conducted. In addition, long-term meteorological monitoring has been performed in 4 meteorological stations located at 800, 1000, 1400 and 2500 m elevation. Forest Research and Management Institute (ICAS) in Bucharest and Brasov, Department of Ecology of the University in Bucharets, and Biological Research Institute have been involved in research activities in the Bucegi Mountains (Ion Barbu, personal communication).

The Rarau Mountains are located in the Eastern Carpathian Mountains. The forested area of the mountains covers about 30,000 ha and ranges between 600 and 1,680 m elevation. The dominant plant communities in the Rarau Mountains are mixed beech and fir forests with additions of planted Norway spruce and pure natural and introduced spruce stands. Other important woody species in the Rarau Mountains are: *Taxus baccata*, *Carpinus betulus*, *Alnus incana*, *Acer pseudoplatanus*, *Juniperus communis*, *Salix silesiaca*, *S. cinerea*, *S. viminalis*, *Ribes grossularia*, *Rubus idaeus*, *Daphne mezereum*, *Vaccinium myrtillus* and *V. vitis-ideas*. There are 18 endemic herbaceous species in the Rarau Mountains, among them *Aconiutum peniculatum*, *Anemone nemorosa, Hieracium transslvanicum*, *Ranunculus carpathicus*, or *Dryopteris filix-mas*. Several rare and endangered species of animals and insects are present: *Lynx lynx*, *Canes vulpes*, *Tetrao urogallus*, *Corvux corax*, *Laspeyresia interruptana*, *Thera albonigrata* and *Calostigia laetaria*. A forest reserve of 408 ha was established in 1913 in Slatioara as an Orthodox Religious Found. Since 1950 the Forest Institute of Research and Management have managed the Reserve. In 1955 addition of a 250 ha buffer zone enlarged the Reserve area. More than 150 scientific papers have been published regarding various aspects of forest ecology research of the Rarau Mountains (Ovidiu Badea and Radu Canusa, personal communication).

The Rodna Mountains are situated in the Eastern Carpathians. About 3,300 ha of the Rodna Mountains has been designated for long-term forest biology research in the Pietrosul Mare Natural Reserve (Biosphere Reserve). The Reserve consists of 1,770 ha of natural forests and 1,430 ha of alpine meadows at elevations ranging between 950 and 2300 m. The dominant plant communities are the mountainous beech forest, mixed forest, boreal spruce forests, open stands of spruce and *Pinus cembra* and alpine meadows. About 650 species of flora have been described for the Pietrosul Mare Natural Reserve. Among them there are endemic species for the Carpatho-Baltic area, such as *Salix kitaibeliana*, *Erysimum wittmani*, *Thymus pulcherrimus*, *Campanula carpatica*, *Leontodon pseudotaraxaci*, or *Centaurea mollis*. *Lychnis nivalis*, *Soldanella hungarica* spp. *Hungarica*, and *Saussurea porcii* are specifically endemic for the Rodna Mountains. Some of the protected species are *Leontopodium alpinum*, *Gentiana lutea*, *Gentiana punctata*, *Angelica archangelica*, *Pinus mugo*, *Pinus cembra*, *Taxus baccata* or *Rhododendron myrtifolium*. Scientific research in the Rodna Mountains has a long history, with the first description of endemic species in 1788-1795. Extensive geological, geomorphologic, botanical and ecological investigations have been performed in the area. In the last 50 years, scientists of the Forest Research and Management Institute performed many forestry studies in the Rodna Mountains. Major research tasks for the Rodna Mountains are: better understanding of sustainable management at a level of forest ecosystem and landscape; application of the existing monitoring programs into long-term ecosystem research; examination of silviculture practices in long-term forestry experiments; establishment of a model forest (center of excellence) integrating long-term forestry/biology research with various social and economic considerations (Ion Barbu and Ovidiu Badea, personal communication).

Slovakia

The Polana Mountains Biosphere Reserve is an ancient stratovolcano with an outstanding geological and geomorphological structure. Polana rises about 1000 m above the surrounding Slatinska Basin in central Slovakia. The Reserve has well preserved ecosystems of mixed and coniferous forests representative for the middle range of the Western Carpathian Mountains. Polana BR is characterized by a common occurrence of thermophilous and mountain plant species. The original species composition has changed on many sites due to intensive human interference since the 17th century. The remnants of beech-oak and oak-beech forests remain only on southwestern foothills. Besides oaks (*Quercus cerris, Q. petrea, Q. robur)* and beech, these forests include also hornbeam (*Carpinus betulus)*, and lindens (*Tilia cordata* and *T. platyphyllos)*. At present, the most frequent forest communities in the area are beech and fir-beech forests. In addition to the dominant stand-forming beech and fir, the highly productive stands also include Norway spruce, sycamore (*Acer pseudoplatanus*), elm (*Ulmus glabra)* and ash (*Fraxinus excelsior)*. The summits of the Polana BR are covered by primeval spruce stands, representing the southernmost occurrence of indigenous fir forests in the Western Carpathians. Trees in the Polana BR are well known for their extraordinary dimensions due to favorable humus-rich andisols. Riparian ecosystems are shrinking and thus plants of this ecosystem are most valuable and endangered – they include such species as parnassus (*Parnassia palustris),* Siberian flag (*Iris siberica)*, green-winged orchid (*Orchis morio)*, and flowering crocus (*Crocus heuffelianus)*. Rare European yew (*Taxus baccata)* is present on a few sites in the Polana BR. Among the rarest species are: damees rocket (*Hespris nivea)* and Sudetic pansy (*Viola sudetica*). Also the fauna of the Polana BR is very rich and includes many biogeographically outstanding and biosociologically significant species. There are 172 species of birds, and 121 species nest in the area. Mammals are also well represented with several species of bats, critically endangered otter (*Lutra lutra*), about 40 brown bears, northern lynx, and wolf. The great beauty and diversity as well as its cultural heritage was the reason for declaring the Polana Mountains a biosphere reserve in 1990 (Voloscuk, 1999). The Polana Biosphere Reserve is a candidate for a national park status.

The Slovak Karst Biosphere Reserve is located in southeast Slovakia near the border with Hungary. The Slovak Karst BR has an area of about 36,170 ha and is surrounded by a protective zone of 38,330 ha. It consists of a series of plateaus ranging from 400 to 900 m elevation. The basic geological unit is the Silica Nappe. The Slovak Karst is the largest karst region in Central Europe and has a well-developed karst relief and an almost complete karst phenomena of the temperate climate. Typical for this biosphere is a lack of running water with nearly whole precipitation being infiltrated by limestone through numerous fissures and faults into karstic carbonate rocks. The Reserve has a rich system of underground caves. The Slovak Karst has variety of habitats and highly diverse vegetation reflecting its climatic and geological conditions. The most typical forest are the Carpathian oak-hornbeam forests and xero-thermofillous oak forests on alkaline bedrock. They are floristically very rich representing both steppe-forest and sub-mediterranean species, with more than 1,450 vascular plant taxa including 70 protected species. The most important species are: Klastersky's willow grass (*Draba klasterskyi*), Turna golden drop (*Onosma tornensis*), jurinea (*Jurinea mollis* sp.), and six species of mountain ash (*Sorbus bukkensis*, *S. carstica, S. hazslinsz-kiana, S. huljaki, S. tuzsoniana*, and *S. zolyo*mii). There is also a rich riparian flora represented by such species as spiked speedwell (*Pseudolysimachion longifolium*), or sedge (*Cerex buekii*). Flora and fauna contains many protected species. Among the insect population the most interesting are: *Papilio machaon, Iphiclides podalirius, Parnassius apollo, P. mnemosyne.* Slovak Karst was proclaimed a protected landscape area in 1973, a biosphere reserve in 1977, and a World Heritage Reserve in 1995 (Voloscuk, 1999).

Description of the forest ILTER sites for the Czech Republic (Krkonose Mountains, Sumava Mountains and Krivoklatsko), for Hungary (Sikfokut Forest and Kiskunsag Forest-Steppe), and for Poland (Bialowieza, Kampinos and Bieszczady National Parks) has already been provided (Waide et al., 1998).

The ILTER forest sites officially endorsed by the governments or the national academies of science of individual countries in Central Europe (October 1999 status) are presented in Figure 1.
It is planned that other forestry sites from Croatia, Slovenia and Bulgaria will be added the ILTER network. In this regard, contacts with scientists in these countries will be soon established.

Figure 1. Location of the ILTER forest sites in Central Europe: (1) Kampinos National Park, (2) Bielowieza National Park, (3) Tatra Bi-National Park, (4) Eastern Carpathian International Park, (5) Krkonose National Park, (6) Krivoklatsko Forest, (7) Sumava National Park, (8) Bile Karpaty Mountains, (9) Polana Biosphere Reserve, (10) Slovak Karst Biosphere Reserve, (11) Carpathian National Park (Chornohora Range), (12) Sikfokut Forest, (13) Kiskunsag Forest - Steppe, (14) Rodna Mountains, (15) Rarau Mountains, (16) Piatra Craiuli and Bucegi Mountains, (17) Retezat National Park.

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The International Biodiversity Observation Year 2001-2002

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The International Biodiversity Observation Year (IBOY) 2001-2002, will be launched at the end of 2000, on December 29, designated by the United Nations as the annual International Day for Biological Diversity. IBOY is initiated by DIVERSITAS—the international program for biodiversity science. In 1997, a regional network for DIVERSITAS in Western Pacific and Asia (DIWPA) bought the concept of a Biodiversity Observation Year to the attention of the DIVERSITAS Scientific Steering Committee. There was universal support within DIVERSITAS, and planning began immediately through various meetings and workshops for an expanded international effort.

IBOY's goals are two-pronged: (1) to develop urgently needed global datasets on biodiversity and its contribution to ecosystem functioning and human society, and (2) to showcase biodiversity, raising societal and governmental awareness of the need for its conservation and sustainable management.

The case for an IBOY is compelling. Unprecedented rates of species loss and species invasions threaten the composition and integrity of ecosystems. However, the taxonomic data to assess these biodiversity changes and the ecological information to evaluate their consequences for ecosystem functioning and human endeavors such as agriculture, forestry and fisheries is generally lacking. Even where the data exists, it is often widely fragmented and largely inaccessible. In response, IBOY will spearhead a concerted global effort to (1) advance scientific understanding of biodiversity, (2) incorporate accurate information into policymaking, and (3) increase public awareness of the tremendous importance of biodiversity to their daily lives.

At the core of IBOY is a series of projects, each initiated and directed according to the interests of its participants. This results in a diverse and eclectic portfolio of activities with which to meet IBOY's goals. There are taxonomic initiatives to explore our biological heritage and informatics initiatives to increase accuracy and accessibility of currently fragmented data. There are initiatives establishing links between biodiversity and large-scale ecosystem processes and global change. By the end of 2001, these projects will have collected gigabytes of data on habitats from tropical forest canopies to oceanic abyssal plains, and on organisms from prokaryotes to blue whales. IBOY is developing ideas for synthesis workshops to integrate individual projects and provide add-on value by addressing questions of global significance that cannot be answered by individual projects alone. For more detail on these and other projects, see the IBOY webpage at http://www.nrel.colostate.edu/IBOY.

IBOY is not a funding agency but, though inclusion of projects in the global IBOY initiative, it can leverage support and funds for them. The IBOY secretariat is accepting proposals for projects until mid-2000; selection is based on the project's capacity to bring exciting new dimensions to biodiversity research and education and yield concrete products in 2001 and 2002. Organizers also seek compelling ideas to showcase biodiversity, whether through arts, media, or educational initiatives

Observation—particularly scientific observation—is at the heart of IBOY. To date, nearly thirty international scientific research projects are planning programs in 2001 or 2002 that will survey biodiversity, or collate datasets, for a more accurate picture of global biodiversity. Clearly, biodiversity monitoring is a crucial part of IBOY's mission. The activities of the ILTER network and its ability to integrate multi-site and multidisciplinary results, as well as apply these results to policy and management, offer many possibilities for collaboration with IBOY .

This potential synergy has not escaped the notice of scientists involved in both networks. During April 1999, the National Center for Ecological Analysis and Synthesis (NCEAS) hosted a workshop on Biodiversity Monitoring initiated by Harold Mooney. Fourteen international programs which monitor biodiversity were represented at the meeting, including the ILTER. They discussed: current monitoring activities, significant gaps, how current monitoring efforts can be optimized, what monitoring efforts currently exist, where are the most significant gaps, how monitoring activities can best contribute to the goals of the Convention on Biological Diversity, and how IBOY can contribute to monitoring activities. Workshop participants outlined the tremendous potential of IBOY to augment current monitoring efforts, and create innovative multidisciplinary links.

Two IBOY projects are extensively associated with the ILTER network: the GTOS-NPP demonstration project, coordinated by Dr. Jim Gosz of the University of New Mexico, and a Global Survey of Soil Biodiversity and Decomposition (GSSBD), coordinated by Dr. David Bignell of the University of London. The Global Terrestrial Observing System (GTOS) is an international body coordinating the centralization and distribution of large-scale ecosystem data, including satellite measurements of vegetation type and extent, from the ILTER and other international network sites. The GTOS-Net Primary Productivity (NPP) demonstration project plans to centralize data on NPP, and use it to validate MODIS (Moderate Resolution Imaging Spectroradiometer) imagery and help NASA develop an accurate land-cover data map. For their collaboration with IBOY, GTOS-NPP organizers plan to correlate an as yet undetermined measure of biodiversity with NPP measurements. Participants are working to select an ecologically meaningful taxon (e.g. an indicator species for biodiversity or ecosystem parameters) for which there is sufficient data for the analyses. A further challenge is to find data on comparable spatial scales, as the small-scale nature of most biodiversity data is incompatible with the large-scale GTOS data. Organizers are considering the use of data on birds collected at near-continental scales.

The GSSBD is also a demonstration project of both the GTOS and ILTER networks. In addition to the ILTER, eight international site networks will provide data on links between the biodiversity of soil organisms and rates of decomposition. Long-term data available through these networks, such as climactic records, vegetation descriptions, and ground-based leaf area indices, will allow for the vertical integration of results. The Steering Committee, chaired by Dr. David Bignell, is currently developing a set of standard protocols for measurements of decomposition and sampling of organisms. Particular items under discussion include the spatial extent of sampling, the taxa to be examined, and the substrates - recalcitrant (e.g. wood) and/or labile (e.g. cloth) - to be used globally. The Steering Committee is eager to expand the scale of the survey and is encouraging the participation of soil organism taxonomists.

In addition to these projects that will survey the links between biodiversity and ecosystem functioning across a broad suite of ecosystems, other studies are collecting detailed taxonomic information from specialized habitats. For example, Dr. Neville Winchester of the University of British Columbia is leading a project to survey of microarthropods within tropical forest canopies, with the aim of correlating insect and tree diversity. Other IBOY projects will document biodiversity within specific habitats and ecosystems, such as marine caves, oceanic abyssal plains, and the Amazon Basin. The broad differences of spatial and temporal scale among these projects provide opportunities for integrative syntheses, that will contribute significantly to our understanding of biodiversity patterns across different habitats and scales.

IBOY encourages the use of biodiversity data in efforts for sustainable management and conservation of species and ecosystems. For example, LITUS—organized by Drs. Magda Vincx of the University of Gent, Belgium and Jan Marcin Weslawski of the Institute of Oceanography, Polish Academy of Sciences—will extensively survey the biota of sandy beaches and use the information to develop management recommendations for beaches under the heavy influence of tourism. Dr. Vernon Heywood of the University of Reading plans a synthesis of available information on the wild relatives of agricultural crops to aid in the development of new cultivars. The Millennium Assessment, directed by Dr. Walter Reid of the World Resources Institute, is a 3 to 4-year, multimillion dollar, international scientific evaluation of ecosystem goods and services, designed to build local and national capacities for their management. Dr. Anne McLaren, of the Wellcome/Cancer Research Institute for Cancer and Developmental Biology, is directing the creation of a global bank of genetic capital: DNA samples from endangered species. AmphibiaWeb, a database organized by Dr. David Wake, from the University of California, Berkeley, will document the rapid global decline in amphibians, while the International Coral Reef Observation Year, directed by

Drs. John Ogden of the Florida Institute of Oceanography and Terry Done of the Australian Institute of Marine Sciences, will document the extent and impact of coral reef bleaching.

A number of IBOY projects are compiling data into large, global datasets that will improve the accuracy and accessibility of biodiversity information. Species 2000, lead by Dr. Frank Bisby from the University of Reading, is collecting information on species names —now scattered everywhere from museum drawers to academic journals— to develop an immense catalog of life, that will be available through a single Internet interface. The Ocean Biogeographic Information System (OBIS) is assembling data to produce an ongoing, distributed, electronic atlas of life within the oceans. Based on a concept paper by Jesse H. Ausubel of the Sloan Foundation, OBIS began at a 1997 marine systematics workshop and is now housed at Rutgers University under the direction of Dr. Fred Grassle.

IBOY is clearly an ambitious initiative. Not only will IBOY facilitate the development of high-quality, interdisciplinary, innovative biodiversity science, it will convey the inherent excitement and wonder of biodiversity to audiences beyond the scientific community. Specific programs and project results planned for 2001 will focus a continual spotlight on the explorers of the preeminent scientific frontier of our time: the inner workings of the biosphere itself.

Global Terrestrial Observing System, Net Primary Productivity Demonstration Project: Validation Sites of Hungary, the Czech Republic and the Ukraine

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Introduction:

The Global Terrestrial Observing System (GTOS) was formed by four bodies of the United Nations and the world scientific community following the 1992 Earth Summit. The aim of GTOS is to improve the quality and coverage of terrestrial ecosystem data, and integrate them into a worldwide knowledge base. Together with similar global observing systems for climate (GCOS) and the oceans (GOOS), GTOS has been created in response to international calls for a deeper understanding of global change in the Earth System.

The central mission of GTOS is to provide data for detecting, quantifying, locating and giving early warning of changes in the capacity of terrestrial ecosystems to sustain development and improvements in human welfare. To initiate activities within GTOS, implementation of demonstration projects has been planned. The role of the demonstration projects is to promote the sharing and exchange of terrestrial data, and compare methods used to collect it.

The NPP Demonstration Project:

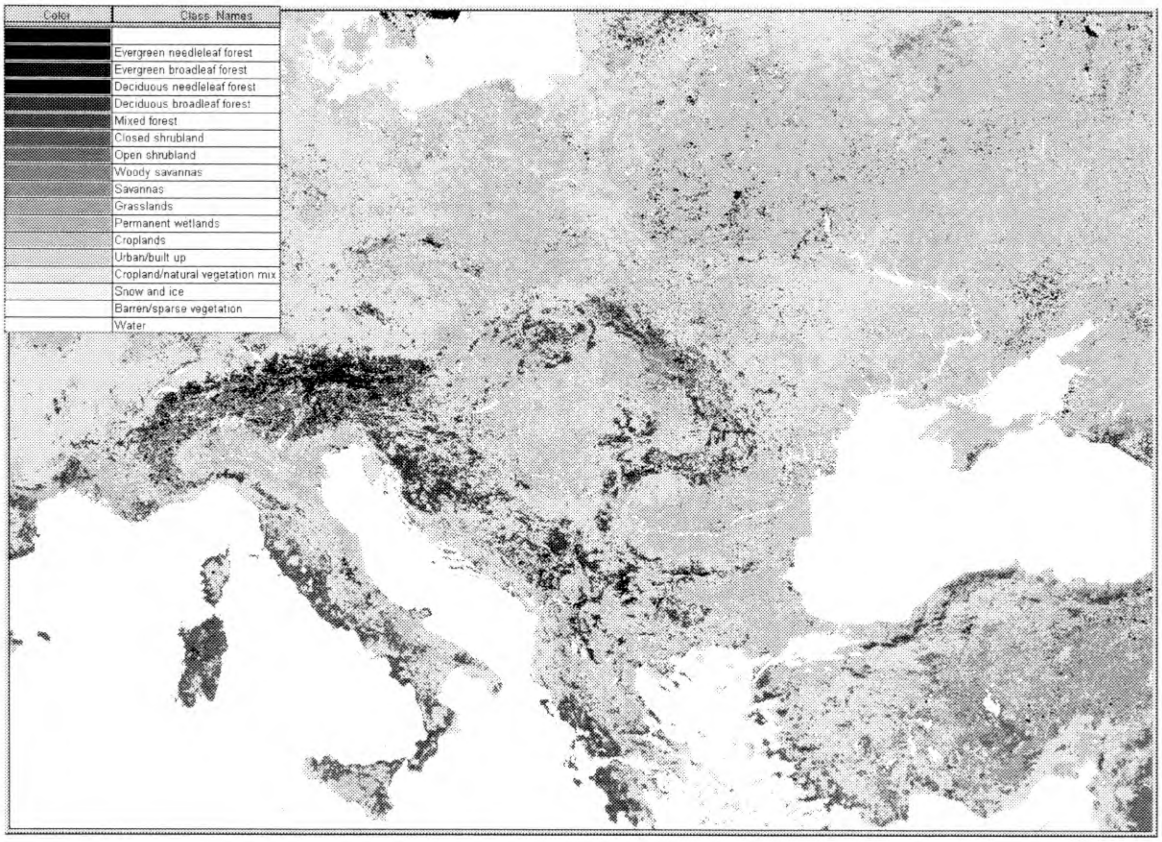
A first demonstration project of GTOS is known as the GT-NET, Net Primary Productivity Demonstration Project (NPP Demonstration project). This first project will serve as a test bed for collaboration among research networks and sites. It will include data sharing and exchange, and help to obtain the experience needed for a further development of the global terrestrial network. This effort is designed to use data from local ecological research sites to compare and validate data produced from the Moderate Imaging Spectrometer (MODIS) sensor of the "TERRA" satellite. The collaboration will be between ecological research sites of GTOS and scientists of the United States National Aeronautic and Space Administration (NASA). Sites will receive data products of basic land cover from MODIS for their site, region or country in exchange for similar land measurements or "ground truth" from their sites. This demonstration project will support the needs for global satellite data validation, and provide global products from advanced satellite sensors useful to sites within the NPP Demonstration project.

The NPP project has two primary goals; first to distribute a global satellite-derived NPP product to regional networks for evaluation, and then translate this standard product to regionally specific crop, range and forest yield maps for land management applications. This will be accomplished by extracting landcover types, leaf area index (LAI), and net primary productivity (NPP) data from the MODIS data stream, and provide it in suitable formats to scientists of sites participating in the NPP demonstration project. Similar validation data of NPP, LAI, landcover or basic climatological information, will be transferred from the participating sites to MODIS team scientists.

Net Primary Production (NPP), is the amount of new plant growth within a given area over a specified time period (g m^{-2} y^{-1}) and is a key integrator of ecosystem function. It is the mechanistic basis of harvest yield, whether it is grass, grain or timber production. Deviation of NPP from its expected value is an objective indicator of ecosystem change, of both degradation and enhancement. To determine NPP values, a set of key input observations such as rainfall, temperature, soil water holding capacity and nitrogen content are needed. In addition, basic land cover type, and Leaf Area Index (LAI) measurements are needed.

The MODIS sensor will be used to compute a NPP product at 1 km resolution. The data will be produced for the entire global vegetated land surface every 8 days using data from the MODIS sensor and other ancillary data such as global digital elevation models. Each participating site must collect reference data to be representative of a 3 km x 3 km square. This is because the calculated NPP product will initially have a resolution of 1 km by 1 km, with a positional error of up to 1 km. Some future MODIS products will have a 250m x 250m resolution. The individual site data will be used as separate validation points for verifying information produced from the MODIS sensor. An example global dataset of basic landcover types was used as an initial point of discussion by participants of the 1999 Hungarian International Long Term Ecological Research (ILTER) meeting. An example subset of these data is shown in figure 1. The data show the basic landcover scheme used by the International Geosphere Biosphere Programme (IGBP) which uses 16 basic landcover types ranging from forest to shrublands to croplands to barren lands, snow cover and water. The primary landcover types of the Eurasian data depicted in figure 1 is of croplands (red) or a mixture of croplands and natural vegetation types (yellow).

Figure 1.
Subset of the IGBP global land cover map covering part of the east European continent.

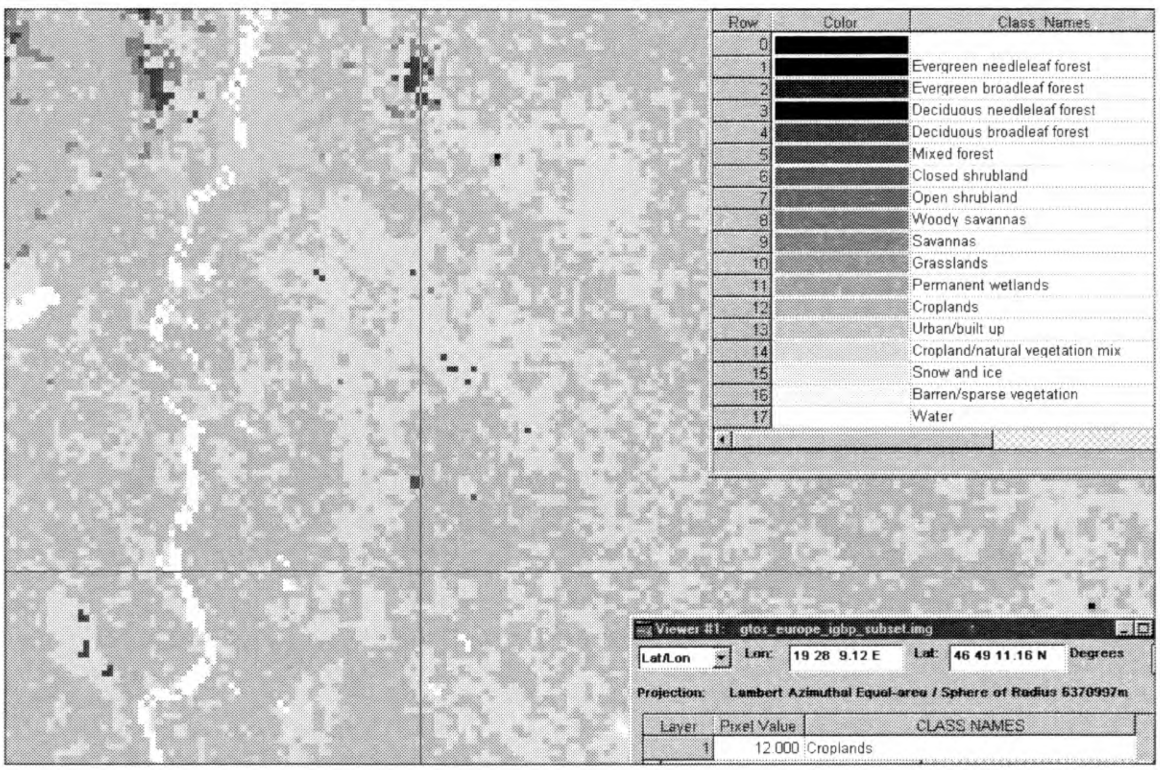


Site sampling scheme:
Validating data for areas as large as 3km by 3km is not a simple undertaking, and in fact determining the value to match the data resolution of the MODIS sensor is difficult. The ability to scale from the natural patchworks of landscapes to a homogenous single measure representing a 1km area is not a simple task. Various methods can be used to take estimates of site measurements and scale them to a 1km or 3km by 3km area. The goal of the estimate is to best determine a single value to be attributed to the coordinates of the central area of the 3km by 3km grid.

A working group of the Hungarian International Long Term Ecological Research meeting considered the three measurements of land cover class (LCC), leaf area index (LAI) measurements, and net primary productivity (NPP) at the 1km and 3x3 km scales. The working group considered schemes to derive an estimate for each of these measurements individually. The determination of basic landcover type was considered to be the easiest, with individual estimates of LAI and NPP scaled to a 3km region, the most difficult. The primary conclusion for a sampling scheme was to determine estimates of each 1km block within the 3km area individually, and then average the estimates together. This average would be attributed to the center 1km area of land for validation of the MODIS satellite data, but the 9 individual 1km estimates within the 3km by 3km area would be valuable data to assist the validation effort.

As a first real example, the Hungarian NPP demonstration project site, near Orgavany was considered. The Hungarian researchers selected a 3km by 3km area of the site, and a detailed landcover map was produced. A 1km grid was superimposed on the land cover classification and the detailed landcover classification was generalized for each 1km block within the 3km area. The region is primarily covered with various grasses, interspersed with differing tree types, croplands, including vineyards, and bare ground. The IGBP landcover map of figure 2 depicts this area as croplands surrounded with a mix of a cropland/natural vegetation mosaic. The participants of the working group determined that the area was best depicted as grassland, and that a large number of LAI and NPP measurements would be needed to properly characterize the region.

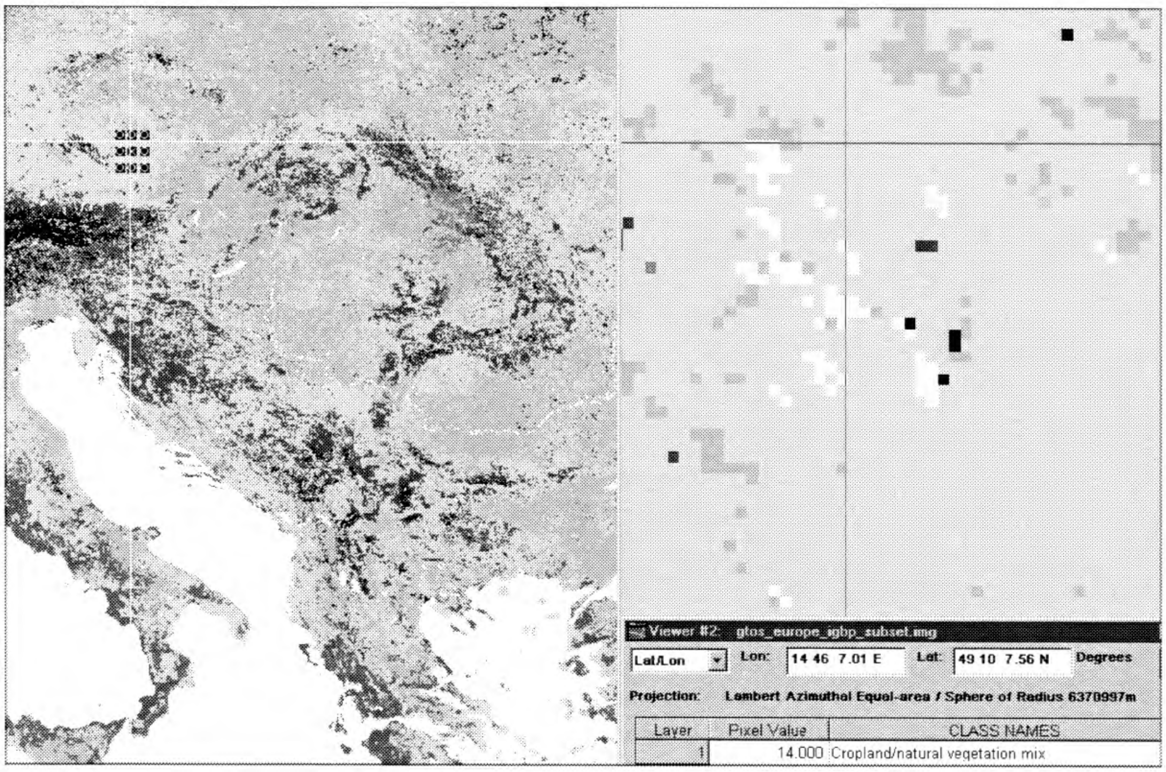
Figure 2.
A magnified subsection of the global IGBP landcover database covering the region south of Budapest, Hungary. The individual blocks of data in the image depict an area 1km square.



A second example was considered to determine a sampling scheme for the Trebon Basin site located within the Czech Republic. The site is an active research area and designated as a Man in the Biosphere (MAP) site. This site and region, with current IGBP land cover estimates, is shown in figure 3. It was determined that four general cover classes would be needed to describe the land cover within the 3km by 3km area at the center of the site. The area is dominated by wetland meadow, and grasses in general. The current central coordinates are classified as a cropland/natural vegetation mosaic in the IGBP land cover classification scheme but is probably more accurately described as a region of grassland and water cover.

Once land cover classes are determined, the timing of LAI and NPP will be important for validation. The Trebon area is harvested in mid-summer. The historic monthly vegetation data for the area show maximal values between May and August. The working group produced a recommendation during the meeting that LAI and NPP measurements should be made at some time between the months of May, June, July or August, with June, as the best time frame. The note of the large change in data and observations should be evident in the weekly composite data generated by the MODIS sensor just after harvest each year.

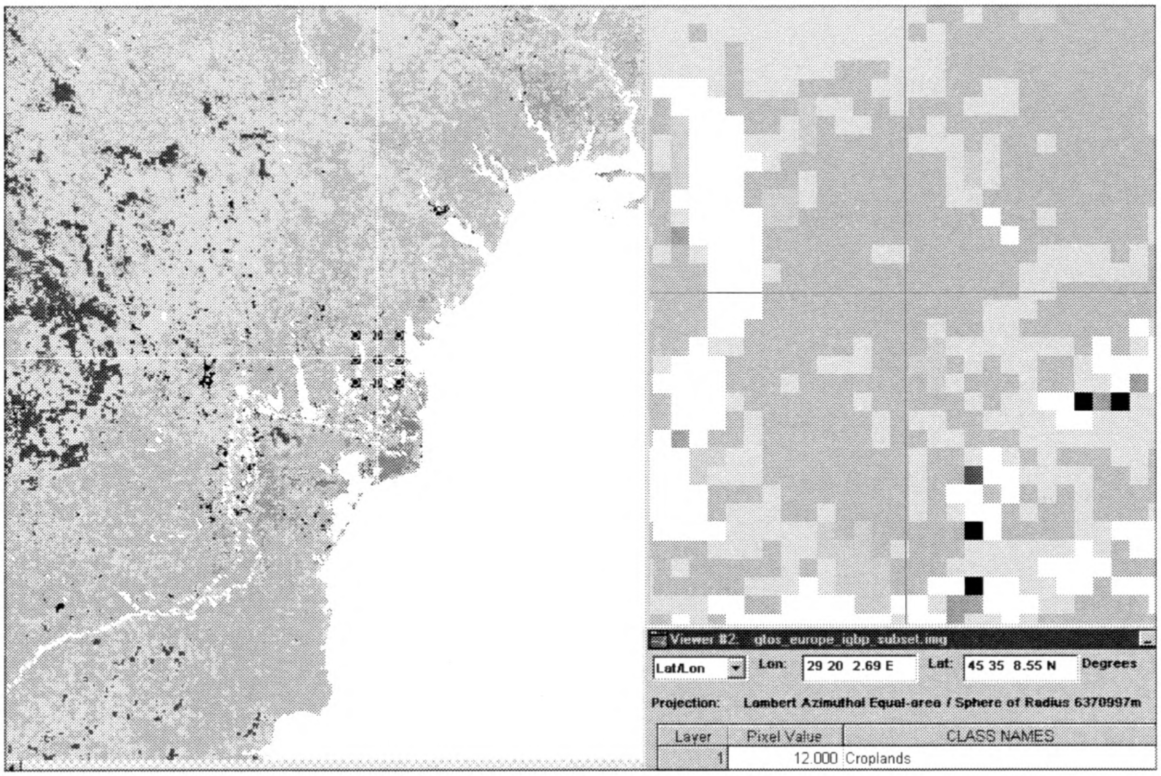
Figure 3.
A large view and magnified subsection of the global IGBP landcover database covering the region of the Trebon Basin validation site.



A third example was discussed for the NPP Demonstration project site within the Danube delta region of the Ukraine (figure 4). This region and site contains a much wider distribution of vegetation types than the previous two examples. It will be more difficult to determine single data values for a 3km x 3km area. The interspersion of water within a matrix of differing land types also complicates determination of landcover types from the satellite-derived data. For example, in the current landcover data there are a number of areas depicted as evergreen needle forest - an error attributed to a wide mix of vegetation types and landcover, including water, within a single 1km area.

These first three sites of the NPP Demonstration project will provide valuable information to validate data produced from the MODIS sensor system. The working group participants realized that the MODIS data at a 1km scale would not be extremely useful for the individual sites. However, the information provided would be extremely useful for extrapolating what is known at the sites to neighboring areas, and especially the region and individual countries. For example, by having access to landcover types and productivity estimates, each region or country could determine changes in various crop yields, or regional impacts of natural disasters such as drought. The data will also be a valuable asset for collaborative efforts to compare local site information with that of other regions of the globe.

Figure 4.
A third example of a NPP Demonstration Project Site - A magnified subsection of the global IGBP landcover database covering the region of the Danube Delta within the Ukraine.



Metadata for Long-Term Ecological Research

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Long-term ecological data are a valuable resource for scientists addressing questions at broad temporal and spatial scales. The interdisciplinary nature of research about global change, biodiversity, and ecosystem sustainability often requires that scientists utilize data collected by other researchers. Physical, biological, and chemical data sets that share a common spatial or temporal domain can be synthesized to model complex ecological systems. In addition, as new research questions arise long-term data are being reused for purposes other than those for which they were originally collected. Because human memory is short, it is vital that long-term data sets be thoroughly documented as they are collected to prevent information loss and to ensure that secondary users of the data can reanalyze it correctly.

To facilitate data reuse and sharing, data sets must be accompanied by detailed information, or **metadata**, that describe the context, content, quality, structure, and availability of the data set. Without metadata, a data set consists only of columns of raw data that are of little value. Metadata are the information that describe 1) what data are in a database, 2) how the data were collected, 3) the objectives of the researcher collecting the data, 4) the scale relevance of the data, 5) how the data set is structured, and 6) other relevant information that may affect secondary use of the data.

Long-term ecological data present special challenges for data documentation. Long-term experiments often go through changes in sampling procedures, instrumentation, personnel, disturbances to the study system such as flooding or fire, or other fluctuations in environmental conditions. Records of these and other factors that cause changes in the data are critical if the ecological significance of the data is to be correctly interpreted. A systematic and standardized way to document and preserve such details is needed.

While metadata standards exist for geospatial data (Federal Geographic Data Committee 1994), no such standard presently exists for non-geospatial data. Michener et al. (1997), however, have proposed a set of generic metadata descriptors that could serve as a standard for long-term ecological data. This system includes five categories of descriptors (Table 1). Category I descriptors include basic attributes of the data set that indicate the temporal and spatial scales of the data, and an abstract describing the study objectives. Category II descriptors include information about the study design, methods of data collection, and the personnel involved in the study. Category III metadata indicate if the data set is available for secondary use, and how recently the data set and metadata have been updated. Class IV metadata describe the structure of the data file, including variable names, variable definitions, and missing value codes. Class V metadata document information related to the data set that may be helpful to a scientist reusing the data, such as publications based on the data set, problems with the data detected by other users, or the availability of voucher specimens.

Documentation of all five categories of metadata descriptors for every data set is clearly impossible due to time and financial constraints. The extent of metadata development depends on who the anticipated secondary data users may be (Michener et al. 1997). If data exchange will occur with expert colleagues, then only Level I and Level IV descriptors are needed. If metadata are to be useful to a broader audience, then Level I through IV metadata are recommended. Level V metadata is always desirable.

Table 1. Proposed metadata descriptors and examples (based on Michener et al. 1997)

Descriptors	Examples
Class I. Data Set Descriptors	
a. Data set identity	Title of data set
b. Data set identification code	Unique identifying code for data set
c. Data set description	Investigator names and addresses; Abstract summarizing research objectives
d. Key words	Location and temporal scale of data
Class II. Research Origin Descriptors	
a. "overall" project description	Identity, originator(s), period of study, objectives of study, descriptive abstract, source of funding
b. "specific subproject" description	Site description (geography, habitat, geology, hydrology, climate, site history), experimental design, research methods, project personnel
Class III. Data set status and accessibility	
a. Status	Latest update, latest archive date, metadata status
b. Accessibility	Storage location, contact persons, proprietary restrictions
Class IV. Data structural descriptors	
a. Data set file	File name, size, format
b. Variable information	Variable names, definitions, units of measurement, range, precision, missing value codes
c. Data anomalies	Description of missing data, calibration errors
Class V. Supplemental Descriptors	
a. Data acquisition	Examples of data forms, digitizing procedures
b. Quality assurance/Quality control	Treatment of outliers, equipment performance
c. Related materials	References and location of maps, photographs, GIS layers
d. Publications	
e. History of data set usage	Log of who used data and for what purpose, comments from secondary users

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The Long-Term Ecological Research Network in Romania

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Introduction

The development of long term ecological research (LTER) at a national scale in Romania resulted from the need to understand and manage the complexity and the dynamics of ecological systems, including socio-economic systems (SES). Our goals were:
(i) to develop and improve the information system for the main components of the country's Natural Capital (NC);
(ii) to ensure complementarity between research and monitoring activities and to minimize costs of implementation;
(iii) to improve the data and information quality concerning structural and functional dynamics of the main categories and driving forces of natural, seminatural and human-dominated ecological systems by taking into account their spatial and temporal organization;
(iv) to develop methodology for extrapolating local findings to a larger scale for comparison with sites from national and regional networks;
(v) to establish the complementarity between the structure, productivity and carrying capacity of the country's NC on one hand, and the structure and metabolism of the national SES, on the other hand, during the transition towards a model of sustainable socio-economic development.

The conceptual basis of environmental science has changed and improved during the transition from "biological ecology" to "systems ecology". Perception of the environment has changed from that of an assemblage of different abiotic and biological factors (soil, water, air, biota and human settlements) to one of a spatio-temporal hierarchy of ecological systems as real organized units (ecosystems, micro and macro landscapes, ecosphaera) characterized by complexity and non-linear dynamics, large space scales and time constants of years, decades or centuries (Odum, E. 1993, Pahl-Wostl 1995, Vadineanu 1998). LTER has became an important tool, complementing basic specific research and integrated monitoring, for the development of the knowledge base for the Information System (IS) concerning the organization, dynamics, productivity and carrying capacity of ecological systems.

The relationships between man and nature, more recently referred to as "development and environmental relationships" should be further reformulated and recast as co-evolution of NC and SES to reflect the new theoretical achievements in the field of ecological economics (Constantza and Daly 1992, Constantza 1995, Vadineanu 1998).

Long Term Ecological Research (LTER) projects have to address each category of ecological systems and be implemented in the framework of large research networks connected to regional and global scales. National networks are the core units supporting the development of LTER knowledge.

This paper reflects our desire to integrate the proposed Romanian LTER sites into the LTER international network. The Romanian network of sites were chosen using an identification process performed by a national academic network and included a series of preliminary actions:

(i) identification of those ecological systems where significant research and monitoring were carried out in the last 6 - 8 decades,

(ii) quality assessment of historical data and knowledge (the identified gaps and uncertainties could became the targets of future LTER and integrated monitoring (IM));

(iii) launching an extensive research and assessment program for the next four years to establish the Romanian ecological network (REN), to identify the reference status for REN and each major category of ecological systems, to reshape and strengthen the integrated monitoring systems, to improve the network of protected areas, etc;

(iv) design and development of the IS for each for the selected sites and the respective guidelines for their management.

At this stage, about 18 macrolandscapes have been identified as components of the Romanian core network of LTER and IM (Fig. 1). This list includes representative sites of the main ecoregions identified on the Romanian territory, most of them belonging to the Lower Danube River System - LDRS (the last 1080 km of the river, including the associated Black Sea coast), the Carpathian Mountains (over 54% of them being located on the Romanian territory) and other terrestrial and wetland systems in the Danube river watershed (covering 99% of the Romanian country surface). For each of the listed sites, the process for description of spatio-temporal organization based on historical data as well as the research and monitoring activities is in different stages of implementation. For some of them, which are presented in this paper, this process is already completed (in italics), while others will be identified in the next four years:

a1. Danube Delta Biosphere Reserve (580,000 ha)
a2. Small Island of Braila (24,000 ha)
a3. Lower Prut River (10,000 ha)
a4. Ciuperceni Wetlands (6,000 ha)
b. Rarau/Dorna/Slatioara (100,000 ha)
c. Pietrosu Mare Biosphere Reserve (44,000 ha)
d. Bucegi/Piatra Craiului (100,000 ha)
e. Retezat Biosphere Reserve (55,000 ha)
f. Iron Gate/Valea Cernei (175,000 ha)
g. Glavacioc/Gavanu (10,000 ha)
h. Apuseni (37,900 ha)

The description of these sites includes the geographical location, the main hydro-geomorphological features, ecological systems, research programs implemented, and institutional and logistic support.

Characteristics of some Romanian LTER Sites

Site a1. ***The Danube Delta Biosphere Reserve***

Location: $44^0$20'40"S, $45^0$27'00"N, $28^0$10'50"W, $29^0$42'45"E.
Mean elevation is 0.5 m above sea level (between 0 – 12.5 m)

Climate

The 45^{th} parallel runs through the reserve and has climatic significance which, associated with the humid nature of the area, has an important influence on the migratory pathways of birds.

Main hydrogeomorphological features:

The Danube Delta is one of the most important wetland areas of Europe because of its biodiversity, surface area and geographical position at the end of the second largest river in Europe (but the first in terms of navigation and connections among Central European Countries and between the Black Sea and the North Sea).

With a surface of 415,200 ha (344,600 ha in Romania, and 70,600 ha in Ukraine), the Danube Delta receives the drainage from 805,300 km^2 and discharges annually about 200 km^3 of water and 26 million tons of solids in the North - Western Black Sea, representing 76 % of the total fresh water input to the sea (Gastescu, 1993). From the total length of the Danube River of 2,860 km, a large lower floodplain (10 - 30 km widths) is associated with the last 780 km just upstream of the delta (Fig. 2).

The Danube Delta Biosphere Reserve (DDBR), with a total surface area of 580.000 ha, comprises six main large hydrogeomorphological units (HGMUs) including not only the 'real' delta between the three arms, Chilia, Sulina and St. George (254,400 km), but the adjacent zones also: Dranov floodplain of 87,600 ha connecting the river with a large complex of lagunar lakes Razim - Sinoe (101,000 ha), secondary Chilia delta (73,200 ha under Ukrainian administration), a limited sector of 50 km of the river stretch and floodplain upstream of the delta (34,000 ha) and the 102,547 ha of the Black Sea littoral waters up to the isoline of 20 m depth (Fig.2). From an administrative point of view, the actual structure of DDBR comprises 50,600 ha of strictly protected area, 253,000 ha of buffer area, and 386,100 ha of transition area (Vadineanu et al., 1998). The current geomorphology of the delta is the result of the interaction between the river and the sea during the Holocene period, beginning some 1,600 years ago.

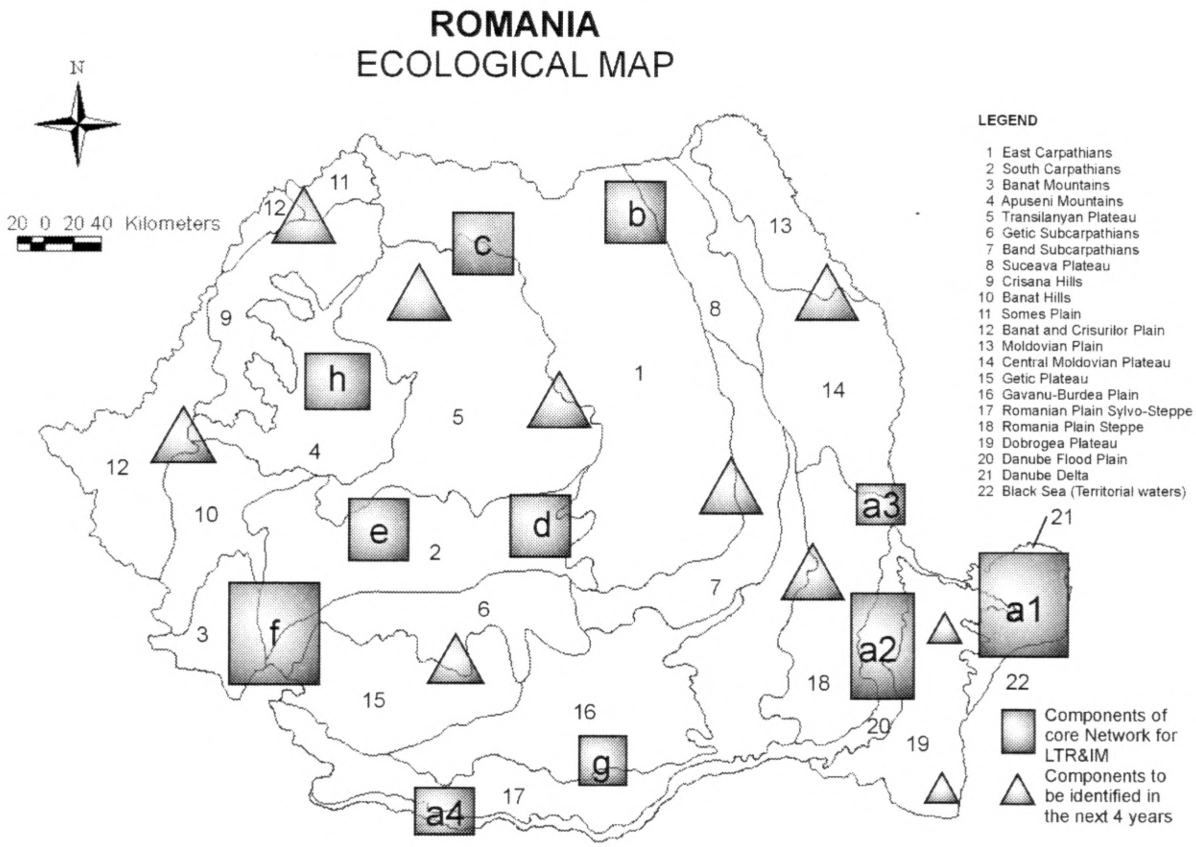

Figure 1. Components of the Romanian Network of LTER and IM.

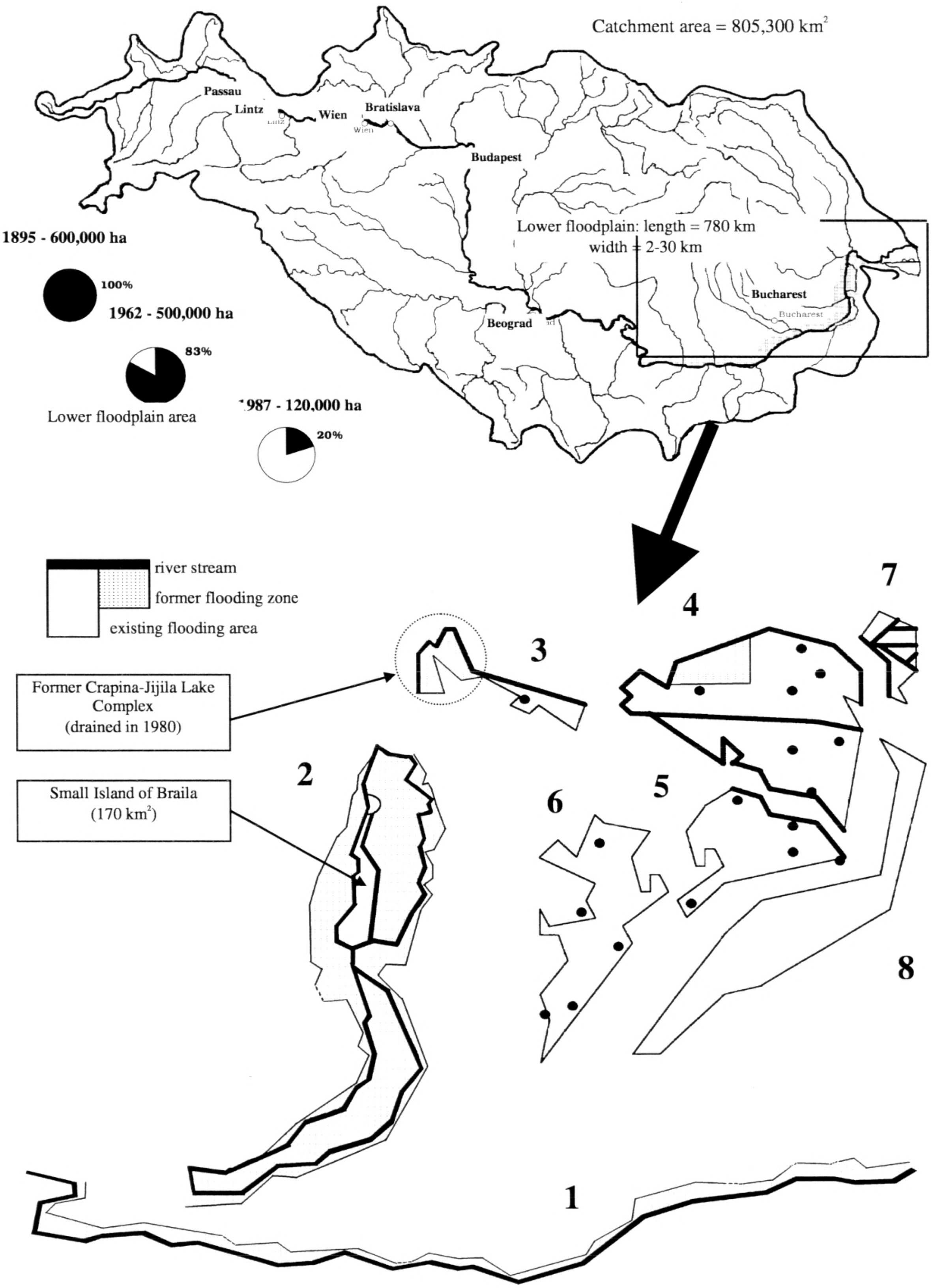

Fig.2 The catchment area of the Danube River including location of the Lower Danube River System (encompassed by quadrat) and of the Lower Floodplain (shadow zone) as well as the main hydrogeomorphological units of the LDRS including Small Island of Braila (2) and Danube Delta (4,5, 6,7, 8).

Main ecosystems:

The Danube Delta is a heterogeneous and dynamic complex of natural and seminatural ecosystems (70%) of various types and in different succesional stages, including lakes, swamps, channels, river branches, reed wetlands, grasslands, dunes, forests (oak and older willow) as well as human-transformed and human-controlled ecosystems (30%) devoted to intensive agriculture, forest plantations (mainly poplar), and fish farming.

The most important surface areas belong to the aquatic and wetland systems (about 44% and, respectively, 37%). The Danube Delta is exceptionally important for a series of ecological values at local, regional and global scales ("landscape and species diversity, buffer and productive potential, natural laboratory, significant contribution for regional and global natural control and tourism"). The very rich and diverse DDBR landscape includes 9 categories of ecosystems, each having its own heterogeneity and leading to more than 50 different habitats (Table 1).

Table 1. Major categories of the Danube Delta ecosystems.

Ecosystem category	Surface area (ha)
1. Natural aquatic	112,000
1.1. Running water ecosystems: the three river branches (269 km) and River Stretch between Galati - Tulcea (50 km), natural (1742 km) and man made Channels (1,758 km).	11,000
1.2. Lakes and ponds including the Lake Complex Razim - Sinoe	101,000
2. Human dominated aquatic (fisheries) 12,000 ha of the former fish ponds established in the 60s are abandoned.	40,000
3. Swamps and bogs 130,000 ha are covered with 'reed beds' (plaur) Very rich ecosystems in both plant and animal species	150,000
4. Frequent flooding areas Important habitat for fish spanning and feeding young fish as well as very productive pasture	86,000
5. Natural terrestrial	25,700
5.1. River bank ecosystem. Small surface are used by local population for traditional agriculture	1,000
5.2 Marine levee ecosystems including:	1,800
Letea and Caraorman Forests	1,400
Bushes	8,100
Sandy steppe	13,400
Vegetation on saline soil	
6. Agro-ecosystems including the largest polders:	53,000
Pardina	27,000
Sireasa	7,800
Carasuhat	2,800
Dunavat	2,500
7. Planted forests	8,200
8. Human settlements (12 rural and one urban ecosystems inhabited by a small local population 15.600 individuals)	2,553
9. Littoral waters	102,547
Total	580,000

The analysis of historical data and those provided by the ongoing process dealing with the updating and improvement of biological diversity descriptions show clearly that the delta system contains very rich communities (Table 2), which encompass at least 1688 plant and 3800 animal species.

Table 2. Species richness in the Danube Delta (from Baboianu, 1998)

Category	Total	New for DDBR	New for Romania	New for science
FLORA				
Alga	562	2	-	-
Fungi	47	5	-	-
Marine fungi	14	-	14	-
Cormophyta	945	409	14	-
Total flora	1668	416	28	-
FAUNA INVERTEBRATES				
Worms	446	101	37	4
Molluscs	106	-	-	-
Spiders	240	66	17	1
Crustaceans	146	10	-	-
Miriopods	34	11	1	-
Insects	2419	312	48	14
Total invertebrates	3391	500	102	19
VERTEBRATES				
Fish	82	-	2	1
Amphibians	9	1	-	-
Reptiles	12	-	-	-
Birds	200	-	-	-
Mammals	41	-	-	-
Total vertebrates	344	1	2	1
TOTAL FAUNA	3735	501	104	20

Research programs implemented:

Basic and applied research carried out in the Danube Delta has yielded much data on hydrology, sedimentology and morphodynamics, structure and dynamics of plant and animal communities, especially entomophauna, structure and dynamics of fish and bird populations, intensive fisheries, poldarisation, intensive agriculture and most recently, rehabilitation of some former wetlands. Unfortunately, little data can be utilized for practical management because of the highly sectorial and small scale approach. Only in the last 20 years has systems-based research developed knowledge at an ecosystem and landscape perspective: (i) a 3 years extensive research program (1980/1982) for identification of types of ecosystems and transition zones and (ii) an 8 years intensive research program on the characteristic water bodies (8-11 representative lakes) in terms of trophic structures, energy flow, heavy metals distribution, biogeochemical cycles of N and P, and primary and secondary productivity (Botnariuc *et al.*, 1987, Cristofor, S., 1986, 1987, Nicolescu *et al.*, 1987,Vadineanu and Cristofor, 1987, Vadineanu *et al.*, 1987, 1992, Cristofor *et al.*, 1992, 1993, 1994, Keller *et al.* 1998, Jamil *et al.*, 1999). Over the same period, the monitoring programmes have changed from a sectorial approach on chemical and physical indicators towards an integrated ecological one.

Institutional and logistic support:

The Management Plan for the Danube Delta Biosphere Reserve was elaborated in 1994 following its new legal status: (i) Biosphere Reserve; (ii) World Heritage Site; and (iii) Ramsar Site. Four zones are delineated: (i) strictly protected areas; (ii) marine and coastal buffer zones; (iii) terrestrial and freshwater buffer zones; and (iv) areas for sustainable socio-economic development (DDBRA, 1995). The Plan comprises 35 Management Objectives and 87 Management Projects.

The administration and management of the DDBR is separate from, but linked to, the local government structures that operate within the reserve. Within the DDBR there are lands under national control, lands under local government control, and land that is privately owned, distributed between seven districts and the town of Sulina.

The body responsible for administration and management is the DDBR Administration that has the status of a regional environmental agency.

The main institutions involved in the implementation of the long term research and monitoring program launched in late 70s are:

- Danube Delta Research and Design Institute/Tulcea;
- Department of Systems Ecology, University of Bucharest (including the team from the Field Station in Braila/LDRS);
- Institute of Biological Sciences/Laboratory of Hydrobiology/Bucharest
- Institute of Geography/Laboratory of Hydrology/Bucharest
- Institute of Geology/Laboratory of Sedimentology /Bucharest
- Romanian Center of Marine Geology and Geochemistry
- Institute for Research and Environmental Engineering/ Bucharest
- Center of Biological Research/Cluj
- "Babes-Bolyai" University/Cluj
- "Alexandru Ioan Cuza" University/Iasi
- Center of Biological Research/Iasi
- Romanian Marine Research Institute/Constanta
- Fish Research Center /Galati
- National Institute of Hydrology and Meteorology/Bucharest

Site a2. ***The Small Island of Braila (Nature reserve)***

Location:
$44^0 47'52''$ S, $45^0 10'25''$N, $27^0 49'05''$W, and $27^0 59'54''$ E, between 0 –12.5m elevation.

Climate:

Mean annual temperature is about 11°C, but a difference of 25°C is recorded between winter and summer mean values. Annual precipitation lower than 500m and quite frequent drought are registered; winds from north and north – east are dominant.
Mean intensity of solar radiation is 1cal/cm^2/min, with maximum values exceeding 1.4 cal/cm^2/min during summer periods and 1.1 cal/cm^2/min in winter.

Main hydrogeomorphological features:

The Small Island of Braila is a component of the Lower Danube River System, a key complex of wetland ecosystems closely related through its long distance connections to regional and global ecological processes.

Upstream from the Danube Delta, between km 175 and km 237 of the Danube River stretch, a large complex of wetlands, shallow lakes, channels, and flooded levees developed from riverine dynamics over a geological time scale. The large hydrotechnical works performed in the last decades have induced structural changes in this inland delta called "Braila Marsh", about 75% of its area being reclaimed for intensive agriculture use. The Small Island of Braila is the most important of the remnant flooding area under natural hydrological conditions, with a very significant role for both actual functioning and potential rehabilitation of the LDRS. It is bordered by the navigable arm of Danube River and one of its secondary arms (Valciu) and encompasses 7 small islands: "Ostrovul Mic": 9625 ha; "Varsatura": 1137.5 ha; "Cracanel": 1037.5 ha; "Chiciu": 280 ha; "Calia": 291.5 ha; "Fundu Mare": 1950 ha; "Harapu" 262.5 ha.

Main ecosystems:

The Small Island of Braila contains representative habitats for the floodplain and for the former inland delta. The total area of 23,000 ha is distributed as follows:

- alluvial forest (18%)
- meadow (24%)
- marshes and cattail swamps (19%)
- ponds (22%)
- Danube arms (18%)

It represents a complex of ecosystems in different successional stages, characterized by a strong connectivity.
Being located at the half way on the migratory routes between sites of Northern Europe and winter refuges from Africa, this complex of ecosystems is well known for its ornithological importance, and thus an integrated management plan for these habitats is a priority.
The available data show that such relatively small scale wetlands contains 14 types of habitats listed in the EU-Habitat Directive, 34 bird species listed in the EU-Bird Directive, and 16 other wildlife species listed in both EU-Habitat Directive and Bern Convention.

Despite the impacts of ecological changes caused by regulation works and eutrophication on many fish and bird populations, the Small Island of Braila has an ecological structure that is similar to the reference system, which was identified based on data from the period 1952-1965.

Research programs implemented:

Two main categories of sources of existing data in the last four decades could be mentioned: a monographic paper on some representative parts of LDRS (i.e. Iron Gates Reservoir, Crapina-Jijila Lakes and the Danube Delta) or on the country animal and plant species (i.e. Romanian Flora, Romanian Fauna).

Since 1990, the research activities performed were targeted on the development of the information and knowledge base concerning the productivity and carrying capacity of this complex ecosystem, the outputs being of a crucial importance in redesigning of landscape structure of LDRS, a priority requirement for the sustainable socio-economic development.

The riparian systems received special attention within these research programs as very sensitive and important ecotonal zones between river and floodplain or between the LDRS and entire catchement area. The first results of national and international programs focused on this problem are very recent and cover large scales (Cristofor et al. 1996) as well as specific compartmental and local scales (Sarbu et al. 1996).

Recent studies were focused on the following issues: i) to characterize spatial heterogeneity of the LDRS in terms of different levels of biodiversity, ii) to describe the main changes induced by human activity on the LDRS structures and iii) to identify the effects of these changes on ecosystem structure in terms of changes induced on communities and species diversity in selected representative zones.

From this point of view the main research programs implemented were:
- Functional Role of Biodiversity (National University Research Council)
- European River Margin System as Indicator of Global Changes (ERMAS I)
- European River Margins System: Role of Biodiversity in the Functioning of Riparian Systems (ERMAS II)
- Functional Analysis of the European Wetland Ecosystems (FAEWE)

Institutional and logistic support:

The " Small Island of Braila" is a Natural Reserve (IUCN IV category), since November 1994 through a statement of Braila County Council No. 20/29.09.1994 and through law no. 137/1995 regarding nature conservation.

An integrated management for the Nature Reserve "Small Island of Braila" was proposed under the European Union's (DG XI) LIFE – Nature 98 Programme. The development of this plan is one objective of Romania's National Strategic Action Plan for Biodiversity Conservation supported by the Ministry of Water, Forestry and Environmental Protection.

Management and administration of Small Island of Braila is linked to the government structures, but has also special administration: "The Administrative Council of the Small Island of Braila".

Main institutions involved in the research programs carried out are:
- Department of Systems Ecology/University of Bucharest (including the team from the Field Station in Braila/LDRS);
- Institute of Biological Sciences/Bucharest
- "Lower Danube" University/Galati

Site c. Pietrosu Mare Biosphere Reserve (44,000ha)

Location:

47°40' N latitude and 23°00' E longitude, located in the East Carpathians – Rodna Mountains.
The elevation is between 900m and 2,303m above sea level.

Climate:

The mean temperature is 6°C at 950m and –1.5° at 2,300m, while the extreme values are: -31°C and 23°C at 1,800m. Precipitation varies between 900-1,400mm/yearly. Mean snow strata is of 90cm and the number of days with snow cover between 100-250/year. Dominant winds are from SW and W, NE and E. Solar radiation at 1,000m is of 114.3 kcal/cm^2/year and 107.5kcal/cm^2/year at 2000m.

Main hydrogeomorphological features:

Rodna Mountains represent the highest massif of all East-Carpathians. The reserve area is located in the richest zone of Rodna Mountains with three branches: Buhaiescu Mare, Rebra and Pietrosu-Picioru Mosului. Some glacial age relicts like cirques, horns, hanging valleys and rock step lakes, give a particular aspect, dominated by sharp peaks and erosional landscape.
From the total area of 44000 ha, the core area has a surface of 8,200ha, including 5,100ha natural and seminatural forests and 3100 ha of alpine shrub-lands and pastures. There is a buffer zone of 11,800 ha and a transition area of 24,000ha.

Solification rock consists of crystalline schists belonging to three series: mezo metamorphic of Bretila, epi metamorphic of Repedea and mezo metamorphic of Rebra.

Main categories of ecosystems:

The dominant ecosystems for the different altitudinal zones and the plant associations and soil types are:
- Mountainous beech forests and mixed forests, characterized by the dominant associations *Symphyto-Fagetum, Phyllitio-Fagetum, Hieracio rotundati-Luzulo-Fagetum, Pulmonarium rubrae-Abieti-Fagetum.* According to the FAO/UNESCO system, soils are mainly Chromic luvisoils.
- Boreal spruce forests (dense stands) in the high mountain zone, with the dominant associations: *Hierarcio rotundati-Piccetum, Leucauthemo-Piccetum, Festuca rubrae-Agrostetum capillari.* Soils are mainly Dystrict Leptosols, Umbric Leptosols and Ferric Podzols.
- At the subalpine inferior level open stands of spruce and *Pinus cembra* are dominant with the following association: *Rhododendro myrtifolii-Pinetum mugi, Vaceinio-Rhododondretum.* Soils are mainly Eutric Leptosols and Haplic Podzols.
- Spruce forest limit in the subalpine superior zone with dominant association: *Rhododendro myrtifolii-Pinetum mugi, Vaceinio-Rhododondretum* and Leptosols and Haplic Greyzems.
- In the alpine zone prairie is dominant, with the characteristic associations: *Caricetum curvulae, Cetraria-Vaccinietum.* Ranker, Regosols, Greyzems and Histosols dominate soil cover.

About 650 plants species are present in Pietrosu Mare, 39% being Eurasian but also endemic species for Carpatho-Balcanic space (7%), endemic for Carpathian (5%) or endemic only for Rodna Mountains (*Lychenis nivalis, Soldanella hungarica spp.hungarica, Saussurea porcii,* etc.).

Research programs implemented:

Research studies performed in Rodna Mountains have focused on different aspects, as follows:

- Detailed geological, geomorphological and pedoclimatic studies, between 1938-1978 (Sarcu, 1978);
- First botanical studies consisting of the description of more than 2,000 species were carried out between 1788-1899.
- Phytogeographycal synthesis 1898-1990 (Coldea, 1990);
- Dynamics of subalpine vegetation under human impact: 1960-1999;
- Mapping of forest cover and evolution of forests in the last 60 years;
- Monitoring of fauna and vegetation under the influence of protection measures in the Biosphere Reserve-Pietrosu Mare: 1967-1999 (Popa, 1999);
- Ecological reconstruction (rehabilitation) of subalpine sites degraded by grazing trough plantation of *Pinus mugo.*

Institutional and logistic support:

Pietrosu Marewas designated as a Natural Reserve in 1979. It was enlarged in 1999 from 3,300ha to 44,000ha. Zonation, development of a new management plan and improvement of the administrative infrastructure are in progress. The administrative authority is "Forest Directorate: Maramures County".

The main institutes involved in the research activities are:

- Biological Research Institute Cluj-Napoca
- Forest Research and Management Institute Bistrita and Campulung Moldovenesc
- Forest Direction – Baia Mare
- Romanian Academy – CMN (Committee of Nature Conservation) – Bucharest
- Natural Science Museum – Baia Mare

Facilities supporting the research activity:
There is a laboratory facility located at 1460m for the subalpine and forest zone and another one near the meteorological station, at 1800m.

Site e: *Retezat Biosphere Reserve (55 000 ha)*

Location:

45°15' – 45°30' N latitude and 23°40' – 23°04' E longitude.
Retezat Biosphere Reserve is located in Romanian Southern branch of Carpathian Mountains, in Hunedoara county.

Climate of region is temperate - continental, influenced by the mountain altitude: it is more cold and humid. The yearly average temperature varies between 6° C on the mountain base and –2 °C on the top; annual precipitation is between 900 mm at the mountain base and 1300 mm and just more at higher altitude.

Main hydrogeomorphological features:

This Biosphere Reserve is mountainous, with altitudes between 650 m and 2,509 m. Most of the Reserve is situated in the Retezat Mountains but some area is in the Godeanu -Tarcu Mountains and Oslea Mountains. The Reserve is 55,000 ha in size, of which 38,047 ha is Retezat National Park, from which 4,600 ha is Scientific Reserve. The rest is used by local inhabitants as forests, grasslands, orchards and arable lands. There are some settlements (11 mountain villages and towns). In the Râul Mare hydrological basin (between Retezat and Tarcu – Godeanu mountains) a dam has been built and some rock deposits and roads have resulted. Danubian metamorphic rocks dominated by crystalline schists compose the ground region of discussion. Mesozoic limestones in the south and south-east of the massive are important sedimentary formations.

Main categories of ecosystems:

Three belts of vegetation are present:

-montane belt comprising the whole forested area of the mountain, with a subbelt of beech (Fagus silvatica) forest (700-1050m) followed by mixed beech and coniferous forest (*Fagus silvatica, Abies alba, Picea abies*) (1100-1350m)and subbelt of spruce (*Picea abies*) (1350-1650m)

-subalpine belt of timberlines spruce forest *Picea abies* and rarely *Pinus cembra*) (1700-2100 m) and *Pinus mugo* shrubs (2250-2500 m)

-alpine belt of primary grassland and low oligoterm shrubs (2250 – 2500 m).

The rich biodiversity of Retezat Biosphere Reserve was expressed by 1180 vascular plants and 1817 cryptogamic species present in the 61 plant associations, each of them with high species diversity.

44% of the plant species are Eurasian but 5.2% of the identified species in the area are rare and endemic for the Carpathians, endemic only in Retezat being 2.0%; One of them, *Draba dorneri*, covers 400 sq. m on the earth.

Most important for genera *Poa* and *Hieracium* is "Gemenele" Scientific Reserve because it is considered an European genetic center; this area is important not only for flora but for fauna too.

Some threatened animal species at the national level were found: 3 fish species, 2 reptile species, 14 bird, 5 mammals, as well as 12 endemic invertebrate species (from 1500 taxons). Among mammals, brown bear, lynx and wolf are spectacular.

In the 700 caves from the carst zone an interesting fauna is found.

Research programs implemented:

Three chronological stages of the research studies performed in Retezat could be noted:

- From 1753 – until the creation of National park Retezat (1935). Studies have been focused on flora, geology and geography of the region.
- From the setting up of Retezat National Park until 1980, investigations have been done on geomorphology, floristics, phytocoenologic, pallinologic as well as on faunistic aspects of the area. Some important monographs have been published (Nyarady 1931,1958, Ienistea 1933, Borza 1934)
- From 1980 up to the present, the research activity was focused on structural and functional dynamics of the ecosystems.

Two volumes of ecological synthesis were published, in 1984 (Recherches écologiques dans le parc national de Retezat, published by Romanian Academy in Cluj Napoca), and in 1993 (National Retezat Park – ecological studies, Brasov).

Institutional and logistic support:

The National Park Retezat was established in 1935, December by law 137, for 13,000 ha area out of which 1840 ha is a Scientific Reserve.

-In 1950 – 1954 it was extended to 20,000 ha, including the carst region Retezatul Mic)

-In 1998 it has been again extended to 38,047 ha

-Lacking its own management, the Park had not the best existence, although there were 6 guardians of CMN of Romanian Academy; therefore, beginning 1999 it will have a new administrative structure.

The first research activity in this area was started in Cluj Napoca:

-Faculty of Biology

-Botanical Garden

-Institute of Biology

Later up to today more scientists from Bucharest have been involved in research activity:

-Institute of Biology – Romanian Academy

-Faculty of Biology and the Department of Systems Ecology, University of Bucharest

-Institute of Forest Research and Management

-Nature History Museum "Gr. Antipa" from Simeria: Dendrological Station (belonging to Forest Institute) from Deva: County Museum – Section of Nature Sciences

Facilities supporting the research activity

- Three houses of the Romanian Academy located at Gura Zlata, Rotunda (on Râul Mare River) and Pietrele (on Nucsoara river) at approx. 800 m altitude offer the space for accommodation.
- In the middle of Scientific Reserve the Laboratory House "Gemenele" (about 1600 m), belonging to the Romanian Academy has the facilities for initial processing of samples and data collecting.

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Long-Term Monitoring Activities in Estonia

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Estonia belongs to the part of Northern Europe that was glaciated during the last Ice Age. Because of this the formation of Estonian biodiversity has had only some 13,500 years to develop. The species balance is still positive and the number of endemics is very low (mostly on a subspecific level). A major blow to Estonian nature took place when the country was included into the Soviet Union. Excessive amount of fertilizers and pesticides was used in the Soviet agricultural system. As a consequence, rivers were rapidly eutrophied and the low oxygen levels of the slowly flowing rivers and shallow lakes were reduced to become oxygen deficient, causing the decline of several benthic organisms. Pesticides caused a decline of weeds, insects and birds. Since independence, Estonian nature has had a short time to recover from Soviet time pressure.

Since 1994, the state monitoring in Estonia has been carried out by the Estonian Environmental monitoring programme (EMP) and funded from the state budget as ordered monitoring work. In 1998 the EMP included over 60 subprogrammes with more than 1600 monitoring stations (areas, sites) all over Estonia. The main activities are: air and precipitation chemistry, ground water, surface water and fresh water biota, marine water and biota, coastal survey, landscapes (including remote sensing), forest and forest soil, biodiversity and integrated monitoring.

EMP is "threat-oriented" (climate change, acidification, eutrophication, food contamination, loss in biodiversity, etc). Monitoring work is conducted mainly from research centres and institutes (Tartu University, Agricultural University, Technical University, Vortsjarve Limnological Station, Institute of Zoology and Botany, etc).

Estonia participates also in 5 relevent all European programmes: UN/ECE ICP under convention on long-range transboundary air pollution, CORINE (Coordinated information on the Environment of Europe) programmes on land, water, air and nature, etc.

The Environmental Monitoring Act was approved on 20 January 1999, and a Decree on 5 permanent monitoring sites was also implemented recently. The sites are as follows: Vilsandi, Saarejarve, Soomaa (mire and forest), Karula (South-Estonian forest) and Lahemaa (North-Estonian forest). Now integrated monitoring activities are carried out at Vilsandi and Saarejarve.

Vilsandi:

In 1981 a group of geographers and botanists from Tallinn Botanical Garden began ecological monitoring studies on the West-Estonian islands. The West-Estonian Archipelago Biosphere Reserve was established in 1990. In 1991, when the North-Estonian islands became accessible for researchers, studies were extended to the other islets. Five permanent study areas and four landscape complex profiles have been described in detail (Ratas, Nilson 1993; Ratas, Puurmann 1994). The Vilsandi Monitoring Site (Lat 582303; Long 215101; 0.77 ha) is situated on the Vilsandi island (8.75 km^2) in the 90 years old pine forest. The island belongs to Vilsandi National Park. There are no inland waterbodies at the site area. Mean precipitation level is 570 mm, 14% of which is snow. Yearly mean temperature is 6.1 ^{0}C, hydrological cycle is 262 days long and vegetation period is 187 days.

Within its territory, birds have been systematically watched and protected on the islands of Vaika since 1910, and on Vilsandi and other surrounding small islands since 1971. Episodic botanical and zoological investigations have taken place beginning in the second half of the 19th century. In 1980-1981, two permanent plots of 50x50 m (in pine forest and on alvar meadow) were established for monitoring vegetation and soil. In every permanent plot a sample plot of 10x10 m and four sample squares of 1x1 m were put down. Geomorphology of the study area was described. Lists of vascular plants, bryophytes, lichens, mammals and birds for the whole island , and phyto- and zoobenthos of surrounding sea, as well as maps of landscape and vegetation types of the island have been published. Using satellite imagery, a map of land cover was compiled in 1994 (Nisell, Lindell, Kullapere 1995). Revision of the monitoring objectives occurs every five years.

The changes in vegetation are caused mainly by changed grazing load and natural development of ecosystems. Pollution–caused changes in epiphytic lichen cover, pine bark chemistry and probably in soils are due to long-range transport of air-borne pollutants, since local pollution sources are lacking on the islands. No industry is present on the islands. Land cultivation is confined to growing vegetables for individual use. A small number of domestic animals is kept in households scattered over the island. Seven households are inhabited all the year round and ten others only in summer. The number of summer inhabitants is increasing. The nearest considerable settlement is Kihelkonna in Saaremaa (10 km to SEE, about 500 inhabitants, no polluting industry). The county town of Saaremaa, Kuressaare, lies 40 km to SEE (about 16,500 inhabitants, light industry, central and domestic heating, modest transport).

State of the ecosystem.
Sulphur deposition to Vilsandi is relatively low in comparison with nearby areas: 10.3 kg/ha by precipitation and 7.4 kg/ha by throughfall per year. The load of nitrogen (8.6 kg/ha by precipitation and 4.9 kg/ha per year by throughfall) is higher than in the south of Finland and closer to the south of Sweden (10-13 kg/ha per year) (Nilson 1996). 145 species of vascular plants, 45 species of mosses and 32 species of epiphytes have been found on Vilsandi island. Many of the species are endangered in the other countries of the Baltic area and therefore more attention has to be paid to those. 75-80% of endangered species serve as indicators of nitrogen deficiency. The most pressing environmental concern for endangered species is the increase in nitrogen deposition.

Monitoring network.
'Integrated Monitoring of Air Pollution Effects on Ecosystems' subprogramme stations were established in the intensive area of the site in April-June 1994, and the following parameters are measured: climate, air chemistry, precipitation chemistry, throughfall, stemflow, soil water chemistry, soil chemistry, plant inventory, heavy metals in mosses, foliage chemistry, litterfall chemistry, forest damage, epiphytes, vegetation, microbial decomposition, forest stand inventory. Vegetation has been monitored on the permanent plot since 1981 according to the national monitoring programme (Nilson, Kullapere 1998). During this period, a decrease in cover of grasses, except that of *Lerchenfeldia flexuosa,* and apparent invasion of a moss *Scleropodium purum* have been recorded. The factors that interrupt steady development of vegetation are windfall of trees and damage caused to field and bottom layer by digging wild boars every year. Dying of pines and junipers was found to be the result of a fungal disease caused by *Heterobasidion annosum.*

Small rodents were also investigated in 1990, 1991, 1996. *Apodemus agrarius* was the most numerous and common on the area but was not found in alvar forests (Talvi 1998).

Saarejarve:

Saarejarve (Lat 583926; Long 264532) is situated in the eastern part of Estonia, 35 km north of Tartu. It includes Lake Saare (water area 27 ha, elevation a.s.l. 44.4 m, mean depth 4.2 m, maximum 5.6 m, sediments about 4.5 m, length 790 m, maximum width 700 m, shoreline 2500 m and volume 1134 000 m^3). The monitoring area is 430 ha. Precipitation is 613 mm annually, of which 17% is snow. Yearly mean temperature is 4.5 ^{0}C. The hydrological cycle is 175 days, and the vegetation period is 125 days long. The site was considered to be suitable for long-term monitoring and research. The catchment area is a hydrologically isolated and geologically homogenous drumlin area (clays, sandstones) on middle-devonian sandstone. Land-use is controlled since 1958 by local authorities as a natural reserve, and the land belongs to the state. Local pollution sources are few, and the site is surrounded by a large forested buffer area, dominated by quite undisturbed coniferous mixed communities (Norway spruce and Scots pine), with good representation of common lichens. Vegetation includes pine bogs, fens, birch swamps and grassland. Water inlet to the lake is via four small brooks, and the outlet is one well-defined stream. The area is natural, selectively logged for a long period, but as it belongs to the parish recreation area, no serious disturbance has occurred during last two centuries. Beginning in 1958 the area was protected against logging other than that of dead trees. Earlier investigations include forest inventory every tenth year (last in 1991) and limnological work in

1925, 1934, 1953, 1964. A complex study of the lake was performed in 1951 (hydrology, hydrochemistry, plankton, benthos, fish composition, macroflora). The Forest ecology station of Tartu University is 4 km away, and as part of the International Biological Programme since 1968, scientific research has been carried out (resulting in a detailed energy flow and nutrient cycling model).

Human influence includes recreation and hunting. One small farm is located in the catchment area. Climate data are received from Tiirikoja (26 km NNE) and Tooma (38 km SW) meteorological stations.

State of the ecosystem.
At the Saarejarve catchment area mesoeutrophic forests dominate (32%), with herb-rich mixed forests on wet clay soils (24%) followed by peatland forests (14%) (Frey, Frey, Kask 1996). Nemoral forests are also represented. The tree layer consists of 12 species, predominantly spruce and pine. In the shrub layer, 29 species were found, and the field layer consists of 148 and the bottom layer of 68 species. In the area (136 ha), 1 circular plot per ha, a total of 14 site types were distinguished. The second damage class dominates; lower parts of the catchment show more damage. Appearance of green algae on young spruces (16% of spruce needles of second year branches) shows nitrogen damage from air pollution.

Ammonification takes place in the acidic mor humus layer at relatively low temperature, nitrification takes place only during very warm periods in August and only in the pine stand. In both pine and spruce stands, nitrogen content is very high in mor humus layer, sulphur is concentrating in higher eluvial horizon and heavy metals in illuvial horizon (Frey, Frey 1994). The amounts of percolating water in spruce forest soil was 1.5 times higher than in pine forest soil. About 40% of the soil water measured in the eluvial horizon (10 cm) reaches the elluvial horizon (40 cm). The main difference between the stands lies in the lability of Al and Fe – the concentration of Al being higher in spruce stand and of the latter in pine stand. Higher contents of nitrogen and calcium are leaching from the illuvial horizon of pine stands, whereas in the spruce stand phosphorus is dominating in the process of leaching.

Lake Saare is a highly eutrophic to hypertrophic waterbody. Transparency is 0.7-1.0 m, chlorophyll *a* content (10-86 mg/m^3) and primary production (0.3-141 mgC/m^3) are high, especially in the 1 m surface layer. Lake Saare is slightly alkaline (pH 7-9), and the upper layer of 2 m (BOD7 3 mgO/l) is well supplied with oxygen (9-13 mg O/l). Evidently intensive eutrophication took place in the first half of the 1980s, although some symptoms were revealed as early as in the 1950s. An intensive bloom of blue-greens occurred there in 1951.

Monitoring network.
The studies under the International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems at the intensive monitoring site of Saarejarve include climate, air chemistry, precipitation chemistry, heavy metals in mosses, throughfall, stemflow, soil water chemistry, ground water chemistry, runoff water chemistry, foliage chemistry, litterfall chemistry, forest damage, trunk epiphytes, aerial green algae, microbial decomposition, forest stand inventory and birds inventory (Frey, Frey, Kask 1998).

In 1997 the accumulated ozone exposures over the threshold exceeded proposed critical level for three-month period for crops and natural vegetation during one month (May) (Frey, Frey 1997). The cumulative sum for 5 month period (8612) is near the critical level of forest trees.

The criteria of Ca/Al>1.0 or soluble aluminium concentrations are used for assessing the vitality state of tree roots. In the spruce stand, the ratio was suitable for roots in the depth of 10 cm, but in the depth of 40 cm the data indicate harmful concentrations of aluminium for roots.

Average content of heavy metals (Cd, Cr, Ni) was very different in samples collected during different years. Higher concentrations of heavy metals were caused by flying ash from Estonian and Baltic Power Plants (Roots, Saare, Talkop 1997).

For assessing annual N net mineralisation, the method of incubating soils in buried polyethylene bags was used in field experiments of pine and spruce stands. The results of analysis show that ammonification occurrs predominantly in the acidic mor humus layer of both stands. The N net mineralisation of soil organic matter was slow during the year – 2.1% in the pine stand and 1.7% in the spruce stand.

A bird inventory was carried out in 1998 on 10 ha forest area (50x50 m plots) and at the coastal area of Lake Saare. 16 species are connected with lake, 33 species are casual visitors and 45 are breeding in the forest area (Frey, Frey 1999).

In conclusion we can say that both sites have very low anthropogenic impact and could serve for long-term monitoring and ecological research as changes in vegetation are caused mainly natural development of ecosystems. Pollution-caused changes at sites are mainly due to long-range transport of air-borne pollutants and the results could be used for further studies of transboundary air pollution. Already existing long-term data could serve for future environmental research in different fields. Well-trained staff guarantees a high quality of data and comparability of results to other sites. The already existing national monitoring system with the assistance of a GIS system for coordinated observations and scientific collaboration will significantly improve the interpretation of long-term data (Fig 1).

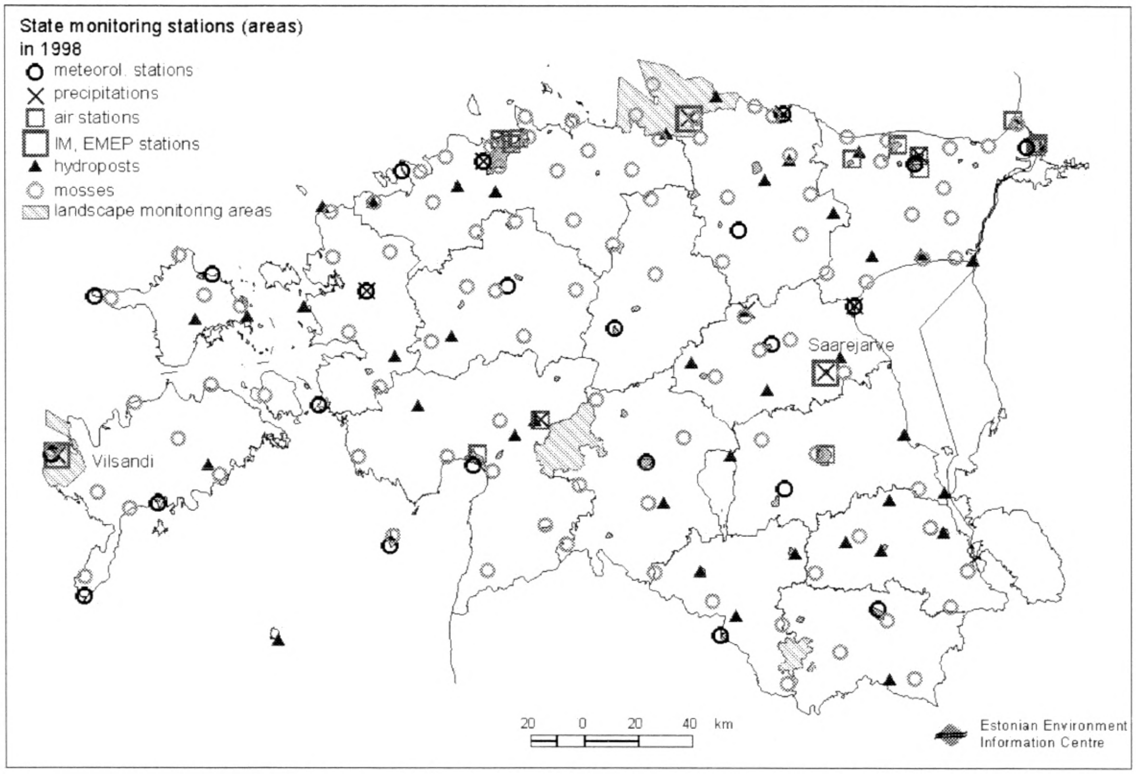

Figure 1 Monitoring sites in Estonia.

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Organization of Grasslands Along Ecological Gradients: US-Hungarian LTER Grassland Cooperation

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Introduction

This US-Hungarian LTER cooperation started with the project "Development of Hungarian-American collaborative research efforts: Biodiversity and Long Term Ecosystem Research" supported by the National Science Foundation (NSF) of the US and the Hungarian Academy of Sciences (HAS) in 1994. This project provided an excellent opportunity for Hungarian scientists to visit several LTER sites in the US where they were able to learn more about the core areas of research, infrastructure standards, the ways of data management, project organization and network activities. The participating LTER sites in the US were the Short Grass Steppe (CPER) site managed by Colorado State University, Sevilleta National Wildlife Refuge (SEV) managed by the University of New Mexico, Andrews Experimental Forest site managed by the Oregon State University, and Kellogg Biological Station operated by Michigan State University. In a complementary visit, US scientists visited the KISKUN LTER site managed by the Institute of Ecology and Botany of the HAS, Research Institute for Soil Science and Agrochemistry of HAS, Plant Protection Institute of HAS, and Eötvös Loránd University. There they learned the techniques and results of former Hungarian biodiversity studies.

As a result of discussions that were based on common interests yet with different expertise and approaches, an interdisciplinary team involving two US and 8 Hungarian ecologists was formed to launch and implement a collaborative grassland research project funded by the NSF, HAS and the Hungarian Science Foundation (OTKA). The project "US-Hungary Grassland Comparisons: Responses of Vegetation to Environmental Constraints" had the aim of developing generalizations concerning controls on grassland composition, structure and dynamics by comparing similar and different types of grasslands on multiple spatial scales on two different continents. Traditional US strengths in experimental and simulation modeling of ecosystem responses were complemented by Hungarian strengths in species diversity and quantitative analyses of spatial interactions to address issues of biodiversity and ecosystem dynamics in the dry grasslands of the two countries. These grasslands are characteristic biomes for these countries and are expected to be sensitive to disturbances, mainly to global climate change. This collaboration resulted in exchanges of scientists and students, participation in conferences and workshops in both countries, comparison of methods (phytocoenology and information statistics in Hungary, experimental and simulation modeling in the US), joint field work in both countries and preparation of common presentations and publications. Electronic communication greatly facilitated interactions throughout the entire period. These joint, collaborative efforts provided research and analyses that could not have occurred from respective, independent efforts of US and Hungarian scientists.

Research Objectives

The specific objectives of the work were 1) to evaluate the importance of current environmental conditions on biodiversity spatial patterns and dynamics characteristic of semiarid grasslands, and 2) to evaluate the short- and long-term responses of semiarid grasslands to changes in environmental constraints, including simulations of potential global climate change. Four hypotheses were proposed for testing.

H1: Small-scale plant biodiversity decreases as variability in precipitation increases and annual precipitation decreases because of an increase in probability of local competitive extinctions (Schlesinger et al. 1990, Abrams 1995).

H2: Landscape-level plant biodiversity increase as variability in precipitation increases because subordinate species have a greater probability of survival in a spatially and temporally variable environment (Noy-Meir 1973).

H3: The rate of change in plant biodiversity or spatial pattern will be greater for sites along a decreasing aridity gradient in Hungary than for comparable sites in the U.S because the amount of precipitation is greater and the rate of competitive exclusion is faster in Hungarian grasslands.

H4: The diversities reach their maxima in the middle part of the aridity gradient in US. The background of this hypothesis is the presence of an ecotone (Gosz and Sharpe 1989, Gosz 1991) between the less arid short-grass prairie and the more arid Chihuahuan desert biome in the Sevilleta site (Gosz 1992).

Materials and Methods

The sites in the U.S. are in different biomes separated by large distances with significant climatic differences producing a considerable semiaridity gradient (Table 1). Sevilleta (SEV) represents a biome ecotone between the short-grass steppe and Chihuahuan desert composed of the elements of both biomes (Gosz and Sharpe 1989, Gosz 1993).

Along the 200 km gradient in Hungary, within the same biome, there are only slight differences in the climatic averages, but the changes of the moisture index (Barley 1979) also indicates increasing aridity. Towards the dry end, the variability of the climatic elements increases together with the role of convective local rain events (Molnár and Mika 1997), which makes the vegetation features less predictable. The changes of the forest - grassland mosaic pattern and humus content of the soil also are important components of the ecological gradient in Hungary.

Long-term data sets in the US from the three LTER sites were combined with data from three sites in Hungary to test the hypotheses. Additional field research was performed in both using the same methods to allow standard cross-site analyses. Vegetation was sampled in 1997 on research areas in each LTER site that were 400 m x 1200 m. Species abundance relations were recorded in 30-50 pairs of 4m x 4m quadrats with a standard arrangement located randomly within each research area, 224 in total.

For detecting fine-scale patterns, presence/absence of species was recorded along 51 m transects composed of 5 cm x 5 cm contiguous quadrats. The classical approaches represent diversity by a simple list of taxa or represent the averaged taxa/abundance distribution detected within a study area. However, coarse resolution sum or average, or other aggregated estimates do not inform us about the details of how species interact and coexist at finer scales. Having recognized that spatial variability and heterogeneity is an inherent feature of vegetation we applied a novel methodology for information statistics (Juhász-Nagy 1984, 1993) that represents diversity by the diversity of species

Table 1. Geographic and climatic characteristics of the sites

Sites	latitude	longitude	altitude	mean ann. temp. °C	mean ann. precip. (cm)	moisture index (Barley 1979)	biome type and dominant grass species
in Hungary							
Gönyüű GY	47°43'N	17°49'E	130 m	10.1	56.5	6.35	forest-steppe, open perennial sand grassland of *Festuca vaginata* and *Stipa borysthenica*
Csévharaszt CSH	47°17'N	19°24'E	140 m	10.2	54.5	6.25	forest-steppe, open perennial sand grassland of *Festuca vaginata* and *Stipa borysthenica*
Fülöpháza FH	46°53'N	19°23'E	130 m	10.3	53.5	6.11	forest-steppe, open perennial sand grassland of *Festuca vaginata* and *Stipa borysthenica*
In the U.S.:							
CPER	40°49'N	104°46'W	1650 m	9.2	32.2	3.87	short grass steppe *Bouteloua gracilis*
Sevilleta SEV	34°21'N	106°53'W	1400 m	13.6	28.0	2.77	transition between short grass steppe and Chihuahuan desert grassland; *Bouteloua gracilis* and *B. eripoda*
Jornada JOR	32°36'N	106°51'W	1280 m	14.1	23.1	2.23	Chihuahuan desert grassland *Bouteloua eripoda*

combinations estimated across a range of spatial resolutions. This new type of diversity, called 'florula diversity' refers to the spatial variability and complexity of within-landscape or within-community local coexistence of species. Because florula diversity is a function of spatial resolution, the scale where it reaches its maximum can be interpreted as the grain of the multivariate spatial pattern, while the maximum value itself refers the intensity of pattern (Juhász-Nagy and Podani 1983, Podani et al. 1993). This methodology is especially useful if we are dealing with the heterogeneous vegetation of ecotones or arid/semiarid regions.

An individual plant-based gap dynamics model (ECOTONE) developed for semiarid and arid grasslands was used to simulate long-term responses of the U.S. and Hungarian sites to current climate and to directional changes in climate (Coffin 1997; Coffin and Herrick 1998). The model simulates the recruitment, growth, and mortality of individual plants on a small plot (< 1m2) through time at an annual time step. Recruitment and mortality have stochastic elements whereas growth is determined by competition for soil water. ECOTONE is linked with a daily time step model of soil water dynamics (SOILWAT) to allow competition for soil water on a daily or monthly time step (Parton 1978). The model was parameterized and run for each site using species information from the literature supplemented with long-term data sets collected at each site. Long-term (20-30y) historical weather data were used along with climate change scenarios generated by global circulation models (Mika 1988, Molnár and Mika 1997).

Results and Discussion

Despite the existing difference in the scale of the between-biome and within-biome gradients, the biodiversity characteristics of the grasslands show similar tendencies. (Fig 1.) Going from the "wet" sites (CPER, Gönyü) towards the "dry" sites (JOR, Fülöpháza) both the average number of species per quadrats and the canopy cover decrease. It is worth mentioning that within the forest steppe biome in Hungary, the slight changes of background factors produces vegetation responses of almost the same extent as those detected between the grasslands of different biomes in the US.

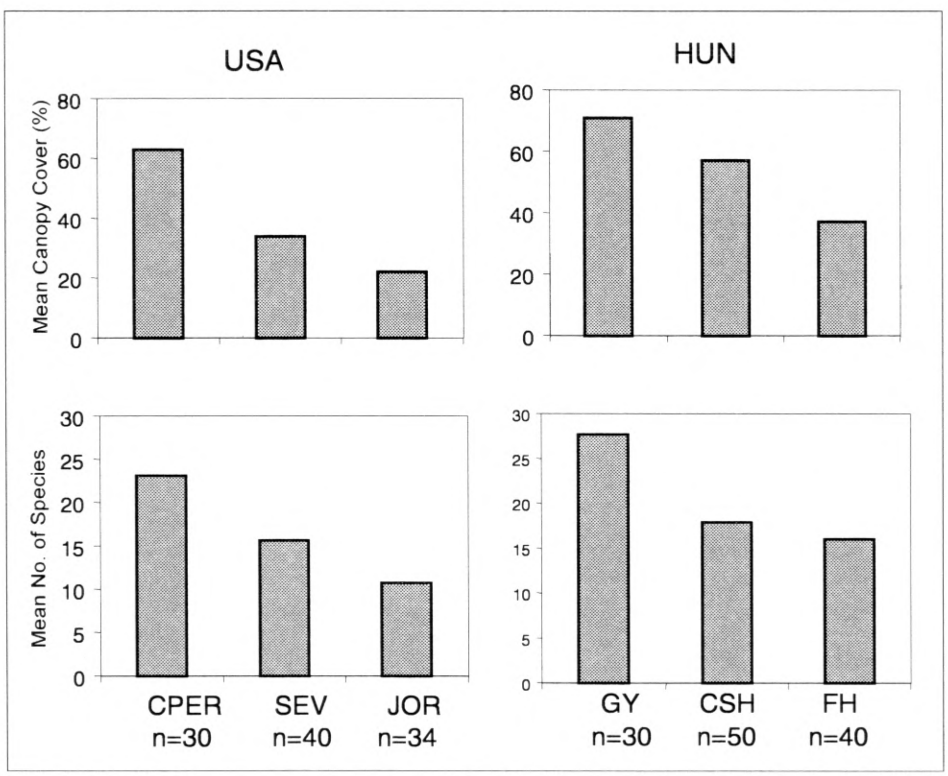

Figure 1. Species richness and mean conopy cover of the 4 x 4 m quadrats. See text for symbols for sites.

Diversity profiles gained by using the Rényi's D diversity index family (Tóthmérész 1995), where the diversity is the order of entropy, show that the Hungarian sites, which are more humid, are more diverse than the U.S. ones when the dominant species have high weight (value higher than 2, Fig. 2). The profiles of the "transitional sites" (SEV and Csévharaszt) change their character depending on how rare and dominant species are considered. When the rare species are weighted with a value = 0, the sites are similar to sites at one end of the environmental gradient; however if the dominant species of these transitional sites are weighted with a value >2, they show similarity to the sites at the other end of the environmental gradient.

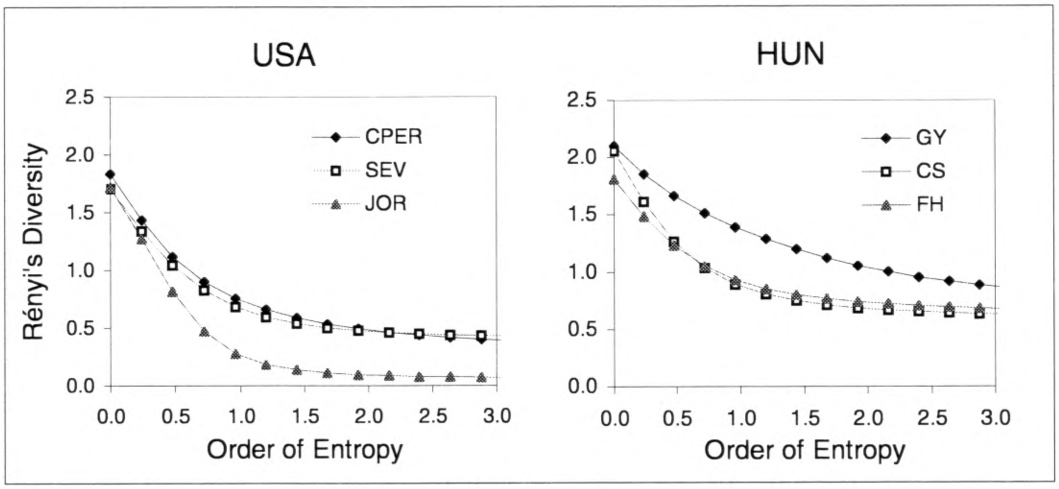

Figure 2. Renyi's diversity profiles of the sites based on species/cover values of the 4x4 m quadrats.

Figure 3 shows the results of comparative analyses of fine-scale patterns. Each point represents a vegetation patch sampled by a 51 m long elliptic transect of contiguous 5x5cm microquadrats. Landscape scale heterogeneity is estimated by repeated samples representing the various types of vegetation patches. Increasing aridity (lower moisture index, fig. 3), was associated with decreasing intensity of multivariate patterns, i.e. decreasing diversity of species combinations. The grain of the vegetation patches increased with increasing aridity, i.e. the maximum diversity appeared at larger sampling unit sizes. Repeated sampling of vegetation patterns were less similar to each other at the arid end of the semiaridity gradient, i.e. the landscape level heterogeneity increases with increasing aridity.

Although the climate data and the derived aridity index (Table 1) appear to be only slightly different among the Hungarian sites, the structural properties of several species indicate there were significant changes in aridity across the sites. The example of *Festuca vaginata* (Fig 4) that is one of the dominants of the perennial open sand grassland, shows that increasing semiaridity results in an increase in the proportion of belowground phytomass both in space (Gönyü - Fülöpháza) and time (June - August) (Kovács-Láng et al. 1989, Lhotsky et al. 1998).

Our modeling analyses for the U.S. sites found that the Sevilleta is more responsive to directional changes in climate compared to the more southern Jornada site (Peters and Herrick 1999). Changes in climate that include an increase in precipitation during the summer are predicted to shift vegetation from shrub to perennial grass dominance at the Sevilleta; at the Jornada, this shift would be to annual and short-lived perennial forbs and grasses rather than long-lived perennial grasses. We also conducted a regional simulation analysis of establishment by the two dominant grass species that included all three U.S. sites. We found that establishment of blue grama (the dominant species at the CPER) decreases from north to south, and the reverse was found for black grama (the dominant grass at the SEV and JOR) (Minnick and Coffin in press). Change in climate that increased temperature was predicted to shift the ecotone northward between these species.

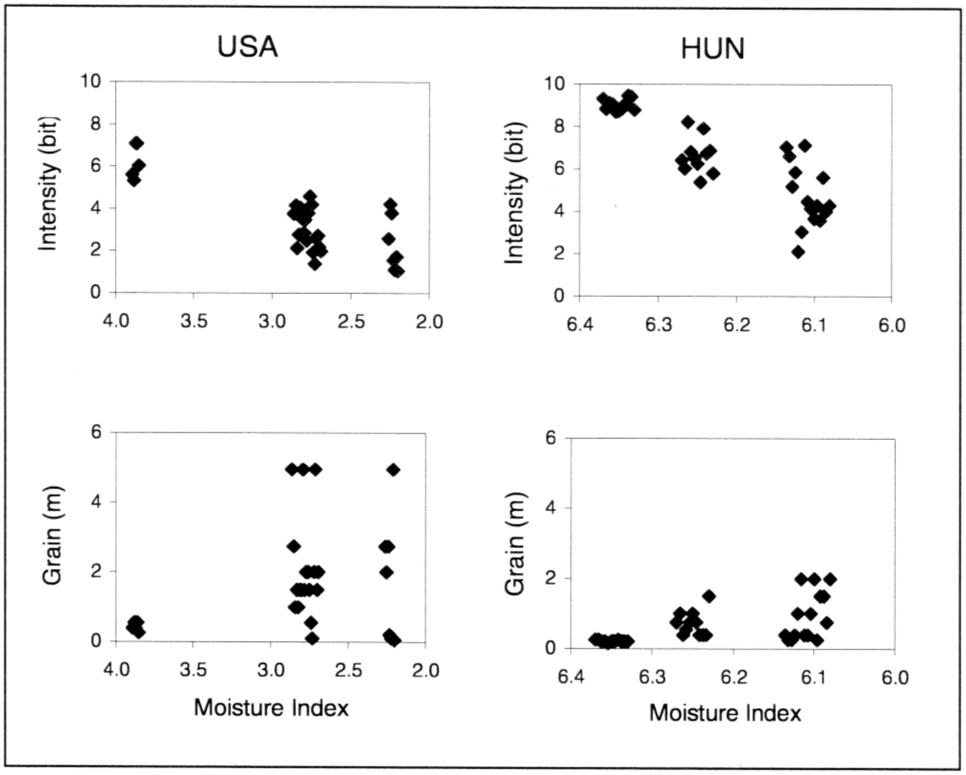

Figure 3. Results of multivariate spatial pattern analyses along the semiaridity gradients in the U.S. and in Hungary. Intensity is measured by the maximum of florula diversity estimated across a range of scales from .05m to 25m. Grain refers the scales of the maximum florula diversity. Each point represents a vegetation patch sampled by a 51 m long elliptic transect of contiguous 5x5cm microquadrats. Landscape scale heterogeneity is estimated by repeated samples of contrasting patch types. Moisture index shows the degree of semiaridity at the sites.

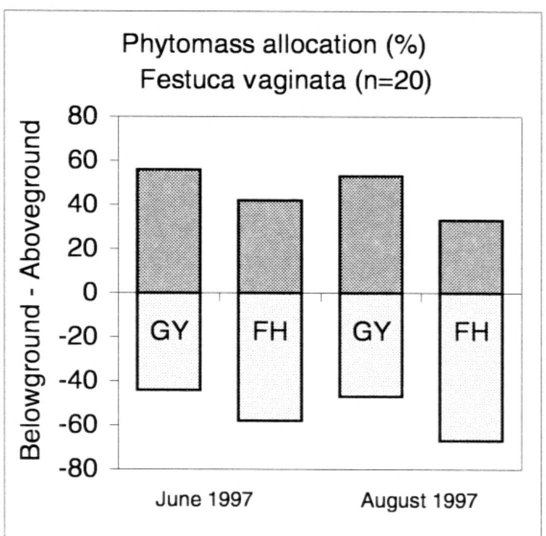

Figure 4. The proportion of above- and belowground phytomass of *Festuca vaginata* in Gönyü (GY, wet site) and Fülöpháza (FH, dry site) in non water limited (June) and water limited periods (August).

For the Hungarian sites, we found that the landscape context has an important influence on the response of the grasslands to climate change (Kroel-Dulay et al. 1999). Model results from the site that contains grassland within a forest matrix (Gönyü) did not correspond as well to field conditions as other sites within a grassland matrix. Additional field studies are needed to determine the processes of importance in generating the patterns in vegetation at this site. In general, the model results indicated that processes associated with recruitment, in particular seed production and seedling establishment, have important effects on grassland dynamics at all sites, yet insufficient information is available on these processes for many species. We have initiated field studies and modeling analyses on these processes for dominant species in the U.S. grasslands (Peters submitted; in review), but additional studies are needed.

However, our preliminary results about the fine-scale interspecific associations supported the gap dynamics conceptualization in the Hungarian grasslands as well (Margóczi 1995, Bartha and Kertész 1998). Figure 5 shows an example when we parameterized the model with Hungarian data (Kovács-Láng 1974, Kalapos 1989, Kovács-Láng et al. 1989). The great temporal fluctuation of the dominance hierarchy at fine-scale (25 x 25 cm) in the simulated vegetation dynamics corresponds well with our field observation at Fülöpháza. The great landscape scale spatial variation found at this site can be understood as a mosaic of many asyncronous micro-successions started after the abandonment of grazing and disturbances caused by military trainings.

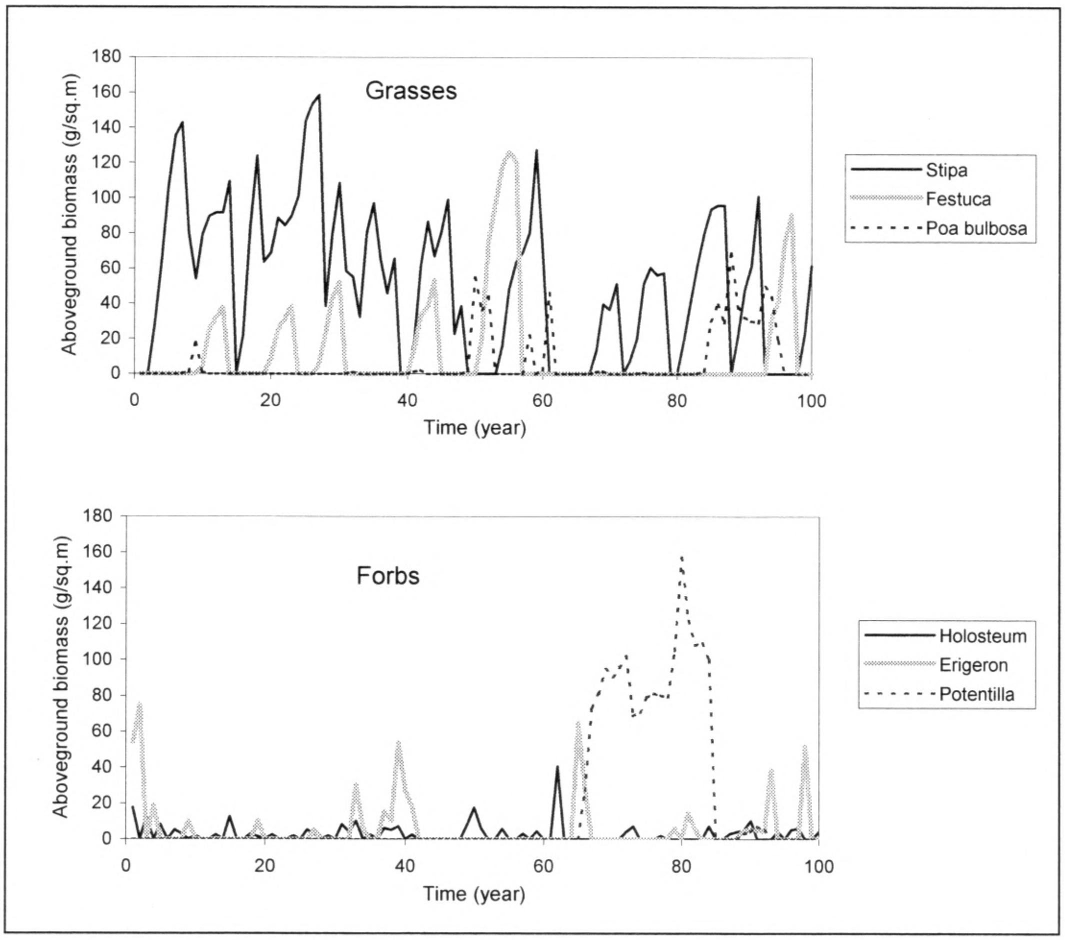

Figure 5. Simulated vegetation dynamics in a 25 x 25 cm area at the arid end of the semiaridity gradient in Hungary. *Stipa* and *Festuca* are perennial bunchgrasses, *Erigeron* and *Holosteum* are winter annuals, *Poa bulbosa* is an ephemeral perennial grass, and *Potentilla* is a long-lived perennial herb.

Summary

Our collaborative US-Hungarian grassland research project had the aim of developing generalizations concerning controls on grassland composition, structure and dynamics by comparing similar and different types of dry grasslands on multiple spatial scales on two different continents.

The evaluation of the importance of current environmental conditions showed that despite the existing difference in the scale of the between-biome (US) and within-biome (Hungary) ecological gradients the biodiversity characteristics of the grasslands and fine scale vegetation patterns analyzed by information statistics show similar tendencies with increasing semiaridity.

Using the same simulation modelling framework (ECOTONE) to synthesize and integrate data from each site allowed us to predict the short - and long-term responses of semiarid grasslands to global climate change.

The ability of this individual plant-based model to represent grasslands outside of the U.S. had not been tested previously, yet our successful application in Hungarian ecosystems indicates the importance of gap dynamics and related processes in grasslands.

By using the same methods to sample diversity of vegetation at multiple spatial scales, we improved our ability to understand controls on grassland structure and biodiversity across climatic gradients. Because our data extend to countries on two continents, our results may have applicability to other semiarid grasslands in the world.

The participating institutions from the US are: the CPER LTER site, Colorado State University, Sevilleta LTER site, University of New Mexico, Jornada LTER site USDA-ARS, New Mexico State University; from Hungary the KISKUN LTER site, Institute of Ecology and Botany HAS, Research Institute for Soil Science and Agrochemistry HAS, Eötvös Loránd University, and the Hungarian Meteorological Service. Research was funded by NSF INT-9513261, OTKA T 016225, and OTKA T 021166.

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Successional Dynamics of Sand Dune Plant and Invertebrate Communities: the Role of Stress and Disturbances

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Introduction

The life of the biocenoses is very dynamic, and is controlled or forced by external or internal factors. Forcing factors may result in a trend in these dynamics, and this trend is called the succession of the community. The background of the changes is often multifactorial, but in each case the role of one or two canonical factors is established. The particular groups of the whole biocenosis are well organised and well-balanced, but may have different responses to environmental factors (Gallé et al. 1985, Györffy and Körmöczi 1987). Since the great complexity of the communities buffers the effect of disturbances that can result in some fluctuation, the real trend of succession can only be discovered in a longer period, sometimes in several decades. This was noticed by many authors, but the investigations are not so numerous.

Kiskunság National Park was founded at 1975, and that was the year we started the long-term study of a grassland habitat on sandy soil. The original aim of the work was to learn the consequences of abandonment of the pasture, i.e. the process of secondary succession of plant and animal communities. Since the climate of that region is rather continental, and the environmental conditions are extreme, the effect of land-use change interfered with other, shorter and longer lasting effects.

The sand dune region of Kiskunság is covered with patchy vegetation due to the large frequency of sand dunes, the undulating terrain, and to the large variation of soil moisture and of microclimate, etc. (Körmöczi 1983). The spatial arrangement of invertebrate communities is similarly mosaic-like, but the size of patches varies assemblage to assemblage.

Responses of different communities to experimental disturbances have been studied for nearly 20 years. Disturbances have included single but serious events of topsoil removal, isolation of stands, and repeated slighter effects of mowing, trampling, watering, and fertilisation. During this period several years of the annual precipitation deficit stressed the communities to change their cenological character. Here we present some examples of the long-term population/community responses to the different kinds of impact.

Effects of climate change on grassland structure

Most habitats of sand dunes in the Kiskunság are strongly affected by the temporal variation of climate, since this area belongs to the arid region of Europe. The year by year fluctuation of precipitation may influence the composition of vegetation due to forcing or retarding the vegetative growth of certain species, but it hardly alters the cenological state of communities (Körmöczi 1988, 1991). Effects of longer period climatic fluctuations, such as several years of serious precipitation deficit (Fig. 1), however, should result in more dramatic change in vegetation structure, even causing the loss of a well defined cenological character.

We started the survey of dry sand grasslands in the late '70s in order to learn more about the effect of land use change on plant and animal communities. The investigation was carried out in the Bugac region of Kiskunság National Park, on a 2.4 ha fenced part of a sand pasture. We intended to observe the community level changes — secondary succession of grassland and invertebrate communities — after eliminating the grazing. Several years of this process showed slight changes in community composition, but the early '80s produced a dramatic change of weather (Pálfai 1995).

The precipitation poor period of about ten years not only interfered with the modification of land use but it became of crucial importance in vegetation changes. Some of the population responses may be considered as the consequence of drought.

Thirteen representative plots were selected in the study area, and 2×2 m permanent quadrats were established to monitor the processes. Percentage cover of each species was estimated. We recorded over 130 plant species in the whole 2.4 ha area, but only 81 species were found in the study plots, 27 of which played the main role in the vegetation changes: *Achillea millefolium, Calamagrostis epigeios, Carex liparicarpos, Carex stenophylla, Cynodon dactylon, Dianthus pontederae, Eryngium campestre, Euphorbia cyparissias, Euphorbia segueriana, Falcaria vulgaris, Festuca pseudovina, Festuca vaginata, Galium verum, Holoschoenus vulgaris, Koeleria glauca, Medicago minima, Molinia caerulea, Ononis spinosa, Poa angustifolia, Poa bulbosa, Potentilla arenaria, Salix rosmarinifolia, Schoenus nigricans, Stipa capillata, Teucrium chamaedrys, Thymus pannonicus,* and *Verbascum lychnitis.* Figure 2 shows the cover changes of four grass species in the mesic wind groove that manifested in the shift of cenological characters.

PCA ordination results of the data from the 1981-1998 period show that three main community types (*Festucetum vaginatae, Potentillo-Festucetum pseudovinae, Molinio-Salicetum rosmarinifoliae*) can be definitely distinguished. Position of each of them changed considerably, and it was mainly fluctuation, although a kind of trend also occurred (Fig. 3). The very different starting positions became closer meaning the homogenisation of vegetation occurred. This is more pronounced in the relationship of *Potentillo-Festucetum pseudovinae* and *Molinio-Salicetum rosmarinifoliae.*

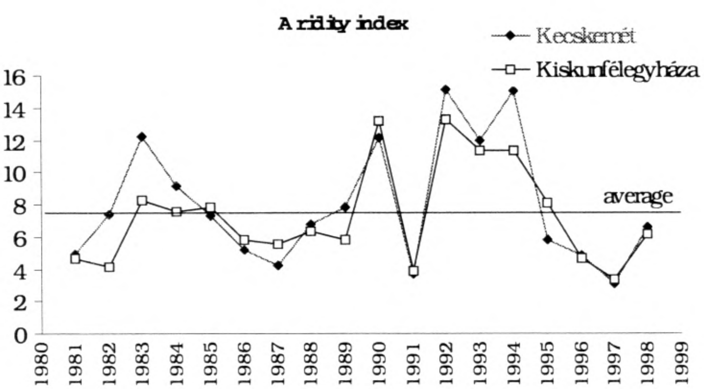

Fig. 1. Changes of aridity index from 1981 to 1998 in the Kiskunság region. (Aridity index derives from annual precipitation, mean annual temperature and ground water level. Higher values indicate more severe drought.)

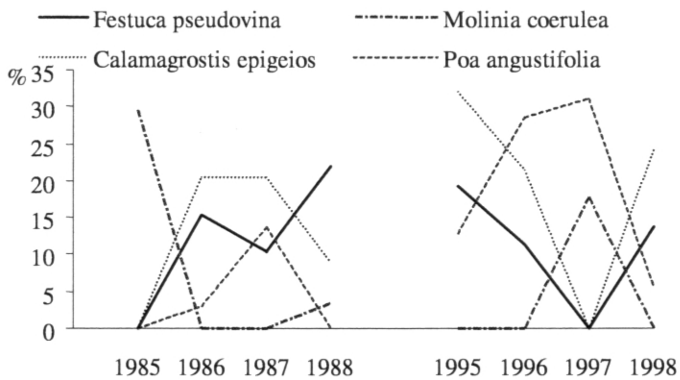

Fig. 2. Percentage cover values of four dominant grass species in one of the mesic stands.

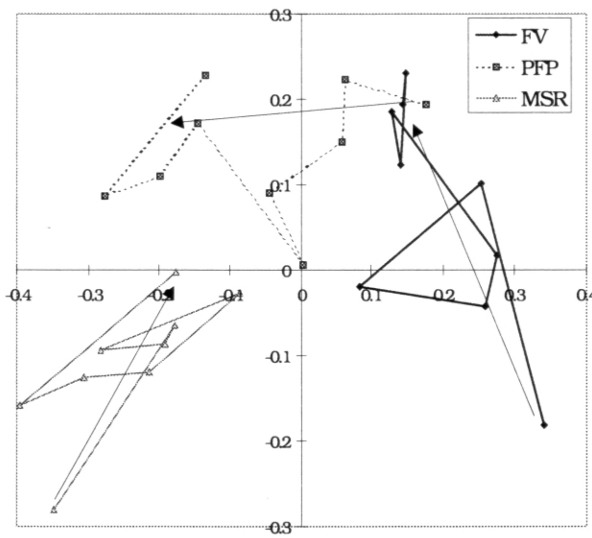

Fig. 3. Temporal trajectories in the PCoA ordination of the study plots. (FV: *Festucetum vaginatae*, PFP: *Potentillo-Festucetum pseudovinae*, MSR: *Molinio-Salicetum rosmarinifoliae*; only one plot per community type was selected!). Arrows indicate the trends of changes from 1981 to 1998.

Stability and regeneration of sand grassland vegetation

The community level stability is a central problem in ecology (Chesson and Case, 1986) A system is deemed stable if the variables all return to the initial equilibrium following their being perturbed from it (Gallé 1998). In specific cases the question is what are the relevant variables, and what is their equilibrium value, if they have any. Only the conclusions drawn from well-documented changes caused by natural or antropogenic disturbances help to prepare a good conservation management plan.

In the Bugac core area of the Kiskunság National Park the present vegetation is a mosaic-like complex of different natural, transitional and degraded stands of sand grassland associations. As a part of the complex long-term ecological study program of the Department of Ecology, JATE University, different management methods (irrigation, mowing and grazing) were tested in study plots representing the two main vegetation types of sand dunes and wind grooves (see Gallé et al. 1991). In order to detect the vegetation changes, the percentage cover values of the plant species were recorded from 1991 in every June and September in permanent quadrats. To study regeneration, 1 m^2 large propagulum free plots were established in eight different vegetation types in winter, 1992. Percentage cover data of regenerating and intact plots were recorded yearly. During the study period 1992-1994 were years of severe drought, in 1991, and from 1995-1998 the weather was less extreme in the region.

Grazing is a traditional management practice in this area, but the number of disturbance tolerant and weed species is considerably higher in the continuously grazed study plots than in the ungrazed ones, meaning a decreased natural value.

The points, representing the differently managed plots are well separated on the PCoA ordination diagram (Fig. 1). There is a difference between the first, dry years and the following normal ones especially in the wind-grooves (Margóczi, 1998). The population level changes in dominance structure, causing this difference to be explained in community level. Species turnover rate was higher in the plots of wind grooves than in the plots in sand dune position. Irrigation decreased and grazing increased this measure in both positions (Fig. 2.).

The speed and manner of revegetation of propagulum free plots was very different in the studied vegetation types (Fig. 3.). Regeneration is fast only if the conditions of the site are optimal for the dominant species (e.g., xerotolerant *Festuca rupicola* or *F. pseudovina* in wind groove position). Recolonization of some dominant species *(Molinia hungarica, Stipa borysthenica, Stipa capillata, Festuca vaginata)* did not occur (or was very low). Presumably the present conditions (especially soil moisture) of the sites are suboptimal for establishment of these species. Clonal plants such as *Potentilla arenaria* or *Thymus degenianus* can occupy the place of dominant grasses temporally. Weed invasion was low, because of the relatively low rate of weed propagules in the seed rain.

The drought influenced the vegetation in Bugac area (see Körmöczi 1994), not only in the performance of plant populations, but the regeneration of communities as well. The described results indicate the decreased resistance of plant communities because of drought and present grazing pressure.

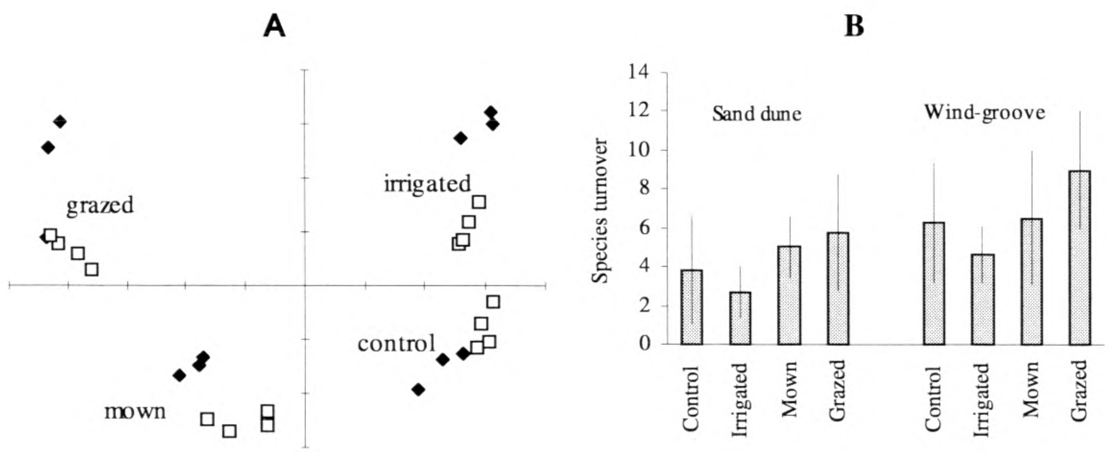

Fig. 4. Effect of different management practices on the vegetation. A: PCoA ordination (using percentage differences) of relevés, made in permanent plots of wind grooves. ♦: first 3 years, a severe drought period; □: the following wetter 4 years. B: Averages of species turnover rates.

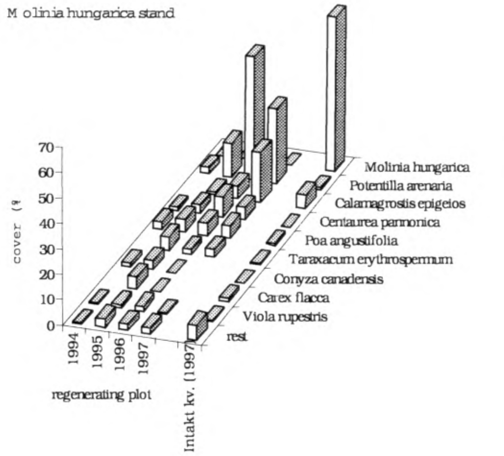

Fig. 5. Species composition of regenerating plots, comparing with an average of intact vegetation in the *Molinia hungarica*, and *Festuca rupicola* dominated stands.

Recovery of Auchenorrhyncha communities in a sandy grassland after removal of the topsoil

Studies of community-responses to different disturbances may help us to estimate the degree of resilience and resistance of communities, as well as to predict the duration and speed of regeneration after disturbances. In the present study our aim was to investigate the reorganisation of Auchenorrhyncha communities after a strong disturbance: removal of the topsoil .

Investigations were carried out on a sandy pasture of the Kiskunság National Park. The main plant communities correlating to the relief were: *Festucetum vaginatae* (FV), a perennial xerothermic grass type; *Potentillo-Festucetum pseudovinae* (PFP), typical for the grazed area; and *Molinio-Salicetum rosmarinifoliae* (MSR), a mesic grass type. A 20 cm topsoil was removed in 1981 from a 600 square meter plot, which represented two characteristic terrains with about 1 m elevation difference. Pitfall and pan trap sampling was continuous during the vegetation period between 1982 and 1988; from 1989 traps worked only four times in a year (Györffy 1995).

The density both of larvae and adults increased rapidly during the first three years. The number of adults was more or less similar in the two terrains, but more larvae developed in the lower one. The larvae/adults ratio reflects the suitability of the biotop for larval development. The more extreme upper terrain seemed to be less suitable, and its suitability changed considerably, especially in the first seven years. The number of species in the surrounding species pool was more than 150, while in the bare plot we collected only 63 (in Barber traps), and 91 (in pan traps) species respectively. The species number was higher in the lower terrain. The values became similar to that of the three control plots after a short increase by the sixth-seventh year. There were many species in the first three years that were not able to colonise.

There was no trend in the diversity and evenness changes in the upper terrain. In the lower one, however, the diversity increased during the first four years, while the evenness remained balanced. This corresponded to the changes of species number. The speed of species turnover decreased from 80% to less than 50% during the first three years (Jaccard index). The rearrangement of species dominance values was faster, and its directionality was higher in the lower terrain. The similarity indices between the Auchenorrhyncha communities of the two terrains reached the maximum values rather quickly. The difference between the species compositions was greater because of some common dominant species.

According to the PCA ordination of samples, the degree of change was higher in the lower terrain. The species composition of Auchenorrhyncha communities on the bare plot became more similar to that of *Festucetum vaginatae* community, but the maximum values were not very high. The species dominance compositions in the two terrains were much more similar to that of Cicadinea communities living in the *Festucetum vaginatae*. The increase of similarity in the lower terrain stopped after the third year.

The directionality of the rearrangement of community dominance composition was higher in the lower terrain. According to the PCA scatter diagram, the trends did not tend towards any of the three control plots (Fig. 6.). Each Auchenorrhyncha community changed considerably during the investigated period because of the continuous drought. Community organisation was probably directed mainly by microclimate and disturbance tolerance of the species. The determinant role of the disturbance- and stress-tolerant species was more characteristic in the upper terrain, but their dominances decreased gradually (Fig. 7.). In the lower terrain the importance of the disturbance-sensitive populations increased rapidly.

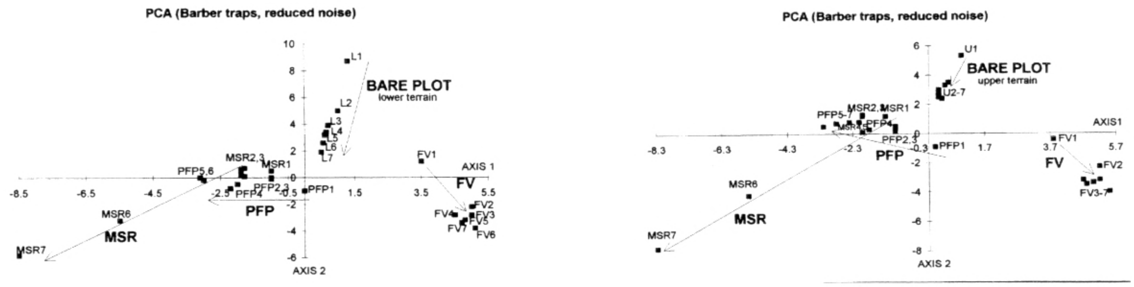

Fig. 6. PCA ordination of Auchenorrhyncha samples from the bare plot and from the three control plant communities. (Barber traps, standardized data, reduced noise.) The letters L and U refer to the lower and upper terrains, the numbers refer to the years after disturbance.

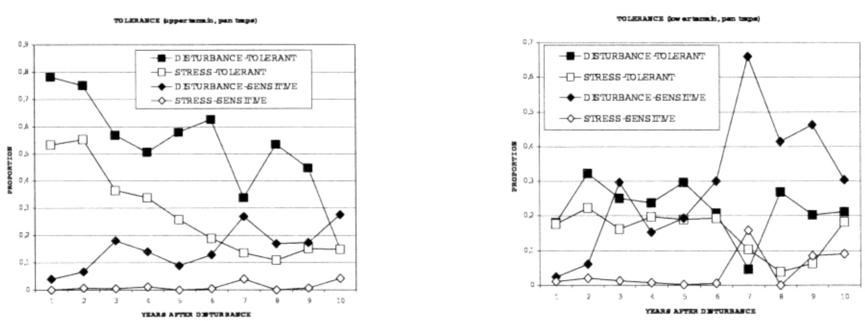

Fig. 7. Proportion of individuals belonging to different tolerance-groups in the two terrains

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A Project-Independent Data Structure for Zoological Studies in Long-Term Ecological Research

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Animal ecological studies are carried out on many different objects, at various spatial and temporal scales. Information originating from diverse projects can be projected into a common data structure (ERIN, 1994; Berendsohn *et al.*, 1996), which consists of data groups about i) the circumstances of the study; ii) the biological object; and iii) the results. A common data structure can make project-independent storage of data possible, which can catalyse co-operative long term ecological studies. Here, a data model is presented, which has a flexible structure to be capable of handling data originating from multiple projects and a wide variety animal ecological studies (Strayer *et al.*, 1986). This data model has been implemented and successfully used for five years in a Hungarian nation-wide faunistical survey of spiders in agricultural habitats. To date the database has data from about 70,000 individuals (385 species), collected in 8200 sampling units. It has proved to be sufficiently structured to successfully serve all kinds of query needs (Samu *et al.*, 1996).

The data model structurally reflects the three main aspects of ecological data sets by having modules for the circumstances of the study, the biological object, and the results. The **Circumstances module** describes the project itself, the experimental design, location of the study and all details of data acquisition. *Projects* are at the highest level of the data structure. Their description promotes the registration of resulting data sets in meta-databases (Horváth *et al.*, 1997; Michener *et al.*, 1997). Projects consist of *experiments*, which are general units of study, that can be a classical manipulative experiment, a survey, or a monitoring study. The places where experiments in the broad sense are done are the *blocks*. In observational studies it is useful to think of a block as a habitat patch. Blocks can be characterised by environmental variables, such as *habitat* type (a recent classification is given in Fekete *et al.*, 1997), by treatment variables in manipulative experiments, and their physical location, the *site* (Dévai *et al.*, 1987; FGDC, 1998). *Samples* are the data recording events in a block that are performed by the application of a sampling program. *Sampling program* is the exact protocol describing how the collecting or observational method is executed, including quantitative attributes, like sample size and sampling effort. The sample data object holds information that can vary relative to the fixed project design and relevant to the data collecting event, such as date, collector, weather, phenological state, host plant and animal.

The quantitative outcome of the study is handled in the **Results module**. Results are obtained from the evaluation of samples. Evaluation consists of classifying animals into homogenous groups, the 'lots', and recording properties (response variables) of these lots. The *catch* data object stores the grouping variables the classification is based on, and the abundance type response variables. Other types of response variables, and their measurement protocols are saved in the *lot variables* and *measurement* objects. The **Taxon module** stores the main criteria of classifying animals into lots, their taxonomical identity. A list of valid *species* (or other taxa) together with their *synonyms*, placement in the taxonomical hierarchy and relevant *properties* (e.g. size, phenology, guild, life form, conservation status) are placed in the data objects within this module.

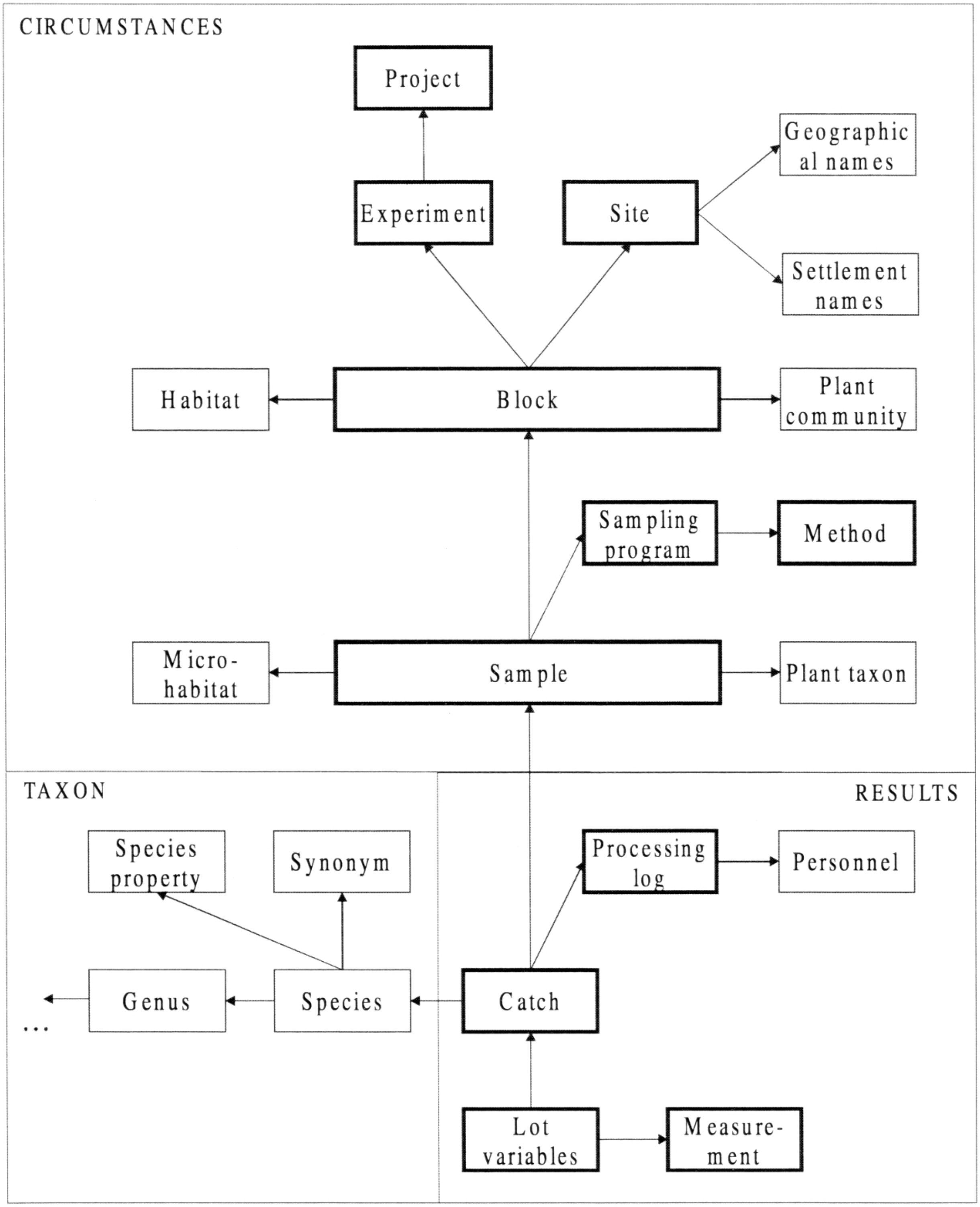

Figure 1. The structural plan of the data model. Main data objects are outlined in bold, choice lists are in plain style. The arrows indicate 'one-to-many' relationship between objects, the arrow pointing towards the 'one' side.

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Meteorological, Hydrological and Ecological Investigations in the Forest Covered Watershed Project "Hidegvízvölgy"

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Characterization of the project area

- The "Hidegvízvölgy" project is located in the central part of the Sopron mountains, in West-Hungary close to the Austrian border.
- The whole territory of the study area is 6 km^2. The altitude is 370-570 m. The climate of the research area is cooler and more humid than the Hungarian average. The mean temperature is 16 ^{o}C in July and the annual precipitation is 760 mm.
- The most frequent forest communities are the hornbeam-sessile oak (*Querco-petreae carpinateum*) and the submountain beech (*Cyclamini fagetum*).

Aims

- Registration of the climate change and the investigation of microclimatologic processes in different forest communities
- Measurement of the input and output of the forested watershed and making its element balance
- Widening our knowledge on the demand and tolerance of the main tree species to ecological factors and studying the water stress and its impacts on the forest communities

Methods

- Measuring of the main climatic parameters (precipitation, wind direction, wind speed, net radiation, air temperature, relative humidity, soil temperature) at tree point of the whole watershed, in a 22-year-old sessile oak stand, and in a 40-year-old beech stand by using a measuring tower with an automatic climate station, and in an open site by automatic meteorological station.
- Measuring the bulk deposition and the interception in different forest stands.
- Measuring the soil moisture content continuously.
- Monitoring the health condition of the forest stands in connection with climate fluctuation and water supply using a raster design (200*200m).
- Measuring of the quality (bed load and suspended sediment; temperature, pH, conductivity, NO3-, NH4+, CL-, PO43-, SO42-, Na+, K+, Ca2+, Mg2+) and quantity of the output streamlet water in two small catchments by

automatic gaging station (trapezoid-notch, sharp crested weir).

Results

The condition of the forest climate, hydrologic cycle and forest ecology are worth examining only on a long time scale. Therefore the work we have done till now is mainly the basis for furthering studies and projects. We have elaborated a system which is available to make a complex hydrological, climatic and ecological examination of the forest lands from the level of the single tree to the level of the watershed. By all means this system takes into consideration local and temporal characteristics. We have established and operated basic units of the research (climatic stations, interception gardens, gaging stations), which are the basis of furthering examinations. We have processed the data continuously. We can do only basic analyses, but we have tried to model the surface runoff processes and elaborated functions for the precipitation-interception relationship.

Landscapes and Vegetation Along a Climatic and Edaphic Gradient: Variabilty of the Sandy Grasslands in the Hungarian Region

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Sand landscapes cover large territories as parts of the Small and Great Hungarian Plains in Hungary. Our attention was focused on closed steppe grasslands as we earlier recognised that their relative importance inside the sand landscapes decreased towards the middle of the basin. Out of the 11 landscapes investigated three are discussed here: from a N-NW - S-SE section the two end-points and one from the middle range. Site 1 (Gönyű) can be found in the Small Hungarian Plain, while Sites 2 (Csévharaszt) and 3 (Orgovány) are parts of the Great Hungarian Plain. These three sites are located along a climatic gradient: in S - SE direction, towards the interior of the basin annual precipitation decreases and the frequency of years with dry summers increases. A more exact climatic description of the three study sites was based on the distribution of the so-called precipitation curve types. At Site 1 for example, the Atlantic-Submediterranean precipitation curve type is more frequent than the Pontic-Submediterranean type, while at Site 3 the opposite applies.

In the studied landscapes 2 ha plots were selected where coenological relevees on a grid (98 points) and raster vegetation mapping were completed with the measure of soil quality parameters (49 points).

On the vegetation maps 7 units occur that represent herbaceous communities and 4 units occur that represent scrubs or forests. Two contrasting groups of grasslands can be distinguished: the semidesert-like open perennial sand grasslands (dominated by *Festuca vaginata*) and the closed-semiclosed steppe grasslands (dominated by *Festuca wagneri,* by *Poa angustifolia,* or the xeromesophilous meadow steppes). At Site 1, characterized by a more humid climate, the plants of the closed steppe penetrate into the *Festuca vaginata* open perennial grassland. This penetration to a much lesser degree also occurs at Site 2. Here, at the fringes of scrub communities the *Poa angustifolia* dry grassland appears as well. At Site 3, however, the plants of the closed steppes withdraw almost exclusively into the meadow steppe that developed (or is developing) from wet meadows; the *Festuca vaginata* grasslands do not contain such elements. The extremely dry habitat is indicated here by the considerable extent of a moss-lichen rich annual grassland.

On the basis of the presence-absence and cover values of the species, clusters of relevees were created by a clustering process. The clusters were used to prepare similarity maps, where a given colour indicates objects that belong to the same cluster. Regarding the vegetation patterns formed this way it could be stated that the separation of the three landscapes from one another is conspicuous especially on the basis of presence-absence values.

For expressing the richness of the quadrats in steppe plants, a system was elaborated where all species were evaluated and scored according to their affinity to steppe grasslands in Hungarian plains (regarding all substrates). So 7-10 scores were given to true steppe plants (generalists to specialists) and, for example, 3-5 scores to plants living in dry forests and also in *Festuca vaginata* grasslands or in meadows. In this way the degree of "steppeness" was mapped. At Site 1 all quadrats bear steppe character, strongly steppic quadrats dominate and quadrats of lower scores hardly occur. At Site 2 quadrats with various degree of "steppeness" occur in relatively equal proportion, extremities are also present. At Site 3 strongly steppic quadrats are rare but considerable number of quadrats occur with no steppe plants.

For characterising the abiotic site conditions, the spatial distribution of organic matter content (an integrated measure of site quality) is demonstrated. At Site 1 high values are characteristic. This can be the consequence of the more favourable microclimate together with the greater forest cover in the past. At Site 2 low and high values as indicators of site heterogeneity occur alternatively. It is the landscape itself that hinders at Site 3 the development of more favourable soils; higher organic matter content could be measured only in few quadrats, on the place of former meadows.

The gradient, along which our sites are situated, starts from the forest biome and ends in the forest steppe biome. We could show that, on sandy substrates having unfavourable water-holding capacity with increasing aridity, semidesert-like communities became dominant. The greatest species richness in steppe plants is connected with the forest climate and not with the forest steppe climate; in the most arid landscape (Site 3) *Festuca wagneri* grassland "loses" almost all of its closed steppe character although the patches of this plant could be observed even here.

The floristic offer of the landscapes -being isolated from one another- is different. This is one of the causes why some communities show segregation according to the landscapes despite their common dominant species, as it could be observed on the similarity maps. The floristic richness (number of steppe plants) does not coincide with the richness in steppe grassland types which is the highest in the landscape with intermediate character (Site 2).

Our results have implications for predicting shifts in species composition as well due to the possible climate change in the future. The plant communities identified do not seem to be equally sensitive to the decreasing precipitation. The quick transformation of meadows to steppe grasslands is expected.

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On the Relationship of Nitrogen Loading and the Vegetation in the Forests of Kőszeg Hills

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The most peculiar symptom of the increasing nitrogen input to the environment is the appearance of nitrophilous plants. It has not been exactly known to which soil features this phenomenon can be attributed. Therefore we wanted to get to know what interrelationships were among soil disturbances and air pollution (nitrogen sedimentation) and the appearance of nitrophilous vegetation in some forest ecosystems.

The place of investigations is in the Kőszeg Hills, along the western boundary of Hungary. In 15 forest stands the relationship between soil features and vegetation was examined. Field incubation investigations were implemented in 4 stands in order to determine the potential rate of nitrogen sedimentation.

Our results indicate that the soil reaction is significantly different in deciduous forests versus conifer forests. It means that the pH in accumulated organic matter of coniferous stands is by 0.5 – 2.0 units lower than under broad-leaved forests. On sites of low soil pH conditions the quantity of accumulated organic matter is the largest. It is the strongly acid reaction and the slowly decomposing needle litter that result in the accumulation of 40 – 60 000 kg/ha organic matter. In Norway spruce forests the soil nitrogen content was less than in hardwood stands. The reason for this is the shallow root-system of Norway spruce, rooting mostly in the uppermost 20 – 30 cm of the soil. The nitrogen mineralized and taken up from the rhizosphere is accumulating on the soil surface due to the subsequent insufficient mineralization, meaning that the nutrient uptake is parting in space and time. Based on field incubation investigations we can calculate the nitrogen surplus of atmospheric origin, but its occurence is not the same on various sites. The comparison of vegetation and soil survey has shown that there is not always a close correlation between ecologic indicators and soil features. From the reuslts of this investigation low correlation coefficients were gained for the total nitrogen% and NB values. Similar statements have been published in the literature, from which the conclusion is drawn that there is no close correlation between total nitrogen content of soil and N-indicator numbers. From the point of view of nitrogen supply the speed of mineralization and the presence of easily available NH_4–N and NO_3–N – even in small quantities – throughout the whole vegetation season have more importance. A similar conclusion can be drawn from the comparison of soil reaction (pH – values) and Borhidi's soil reaction index, meaning that the relationship is rather poor between the two features. We think that the appearance of individual plants is determined by the complex effect of several factors and it cannot be based on only one factor.

Survival and Susceptibility to Photoinhibition of Beech Forest Species After Deforestation at Rejtek Research Site, Hungary

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Clear-cutting of mature forest stands induces severe abiotic stress conditions for the previous understory vegetation. Ecophysiological tolerance and strategies of woody seedlings for survival in this stressful environment are important elements of post-harvest succession and forest regeneration.

In a Beech Forest LTER Site (Rejtek Project, Bükk Mountains, N-Hungary) with shallow rocky soil we have studied the dynamics of secondary succession and ecophysiological background of survival and regeneration of the three major canopy species (*Fagus sylvatica, Fraxinus excelsior and Crapinus betulus*) in a 4 ha clearing created by harvesting a part of the closed mature beech forest stand in the winter 1980/1981. The ecophysiological work has been devoted to gain information on both the short-term (daily) and the long-term acclimation of photosynthetic apparatus, its capacity for utilization and dissipation of light energy and the role of violaxanthin cycle in leaves of sun and shade grown seedlings of canopy trees *(Fagus sylvatica, Fraxinus excelsior, Carpinus betulus)* of the beech forest. In summer months field measurements have been performed in three habitats in the experimental site along belt transects perpendicular to the margin of the remaining forest fragment: in the understory of mature beech forest, in the forest edge of southern exposure and in the adjacent clear-cut area.

The three habitats represent significantly different light climates with respect to the intensity and diurnal variation of PFD. In the forest understory the light intensity ranges between 50 and 200 μmol $m^{-2}s^{-1}$ during clear summer days. This only amounts to 7-10 % of the irradiance measured in the clear-cut area. The light intensity is progressively elevated in the forest edge and in the deforested area and its maximum measured on the leaf surface usually approached a value between 1400-1600 μmol $m^{-2}s^{-1}$ and 1600-2000 μmol $m^{-2}s^{-1}$, respectively. The penetration of light into forest edge zone depends on solar movement, and the duration of the high light period was significantly shorter in this habitat than in the deforested area and was restricted to hours from late morning to early afternoon. In the present phase of succession the success of acclimation of seedlings of canopy trees to high light conditions is reflected well in their height and leaf growth. In every species the specific leaf weight was significantly larger in the clear-cut area and the forest ecotone than in the forest interior. The leaf CO_2 assimilation rate of every species ranged between 1-2 μmol $m^{-2}s^{-1}$ in the forest interior and hardly changed during the day. Seedlings of every species showed the highest photosynthesis rate in the clear-cut area during the day and their daily Pn maximum values occurred between 6 and 10 μmol $m^{-2}s^{-1}$. In the clear-cut area and in the forest edge the photochemical activity of leaves decreased (from 0.74-0.80) with increasing light intensity during the day while in the forest interior the ΔF/Fm' values remained almost as high as at the dawn Fv/Fm values (0.79-0.82). Comparisons on the steepness of slope of ΔF/Fm' light response curves of species reveal that *Carpinus betulus* is the most susceptible species to photoinhibition which is also reflected in the low value of light saturated Pn. In every species clear increasing trends have been observed for the total carotenoid content and especially for xanthophyll cycle pool in response to the light intensity. Among the species *Fagus sylvatica* and *Fraxinus excelsior* have a large violaxanthin cycle pool and their leaves are rich in β-carotene, and *Carpinus betulus* has a small but diurnally a very active violaxanthin cycle pool. It was observed that increased xanthophyll cycle activity appeared as an important factor in acclimation of photosynthetic apparatus of every species to high-light conditions after the canopy openings.

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The Ecological State of the Eastern-Tributaries of the Tisa River - Based on Characteristics of the Physico-Chemical Parameters, the Flora and Fauna

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Abstract

This paper presents multidisciplinary research carried out on the Eastern tributaries of the Tisa River between 1991-1996, which may constitute the basis of long-term ecological research. The present-day status of the different river sectors and catchment areas is given.

Introduction

An intensive, multidisciplinary study on the tributaries of Tisa River was made between 1991-1996 within the framework of several Romanian-Hungarian projects. The study was organised by the Liga Pro Europa - Tg. Mureş, Romania and Tisza Klub - Szolnok, Hungary, and was conducted in the following order: 1991 Mureş, 1992 Someş, 1994 Crişul Alb and Crişul Negru, 1995 Crişul Repede, Barcău and Upper Tisa and 1996 Someş.

Materials and Methods

During this project not only the rivers but also their valleys were studied with special consideration to pedological, botanical and ornithological properties. The studies were performed through screening expeditions. The teams travelled by car along the rivers from their springs until the confluence with Tisa, taking samples from select stations. The sampling stations were selected with respect to their biogeographical characteristics, and the human impact on the valleys and the rivers' courses, while taking into account the potential pollution of the main localities. In order to document the influences of domestic and industrial pollution, we took samples from the main areas of both upstream and downstream riverine settlements. Several geographical, geological, and pedological studies have been completed, and the chemical and physical parameters of the water and sediments have been analysed. The vegetation, phytoplankton, zooplankton, benthon, nekton, ichthyofauna, herpetofauna and ornithofauna were investigated.

Results and Discussion

The research accomplished until now has aimed to establish some primary databases. These databases include the physico-chemical parameters and lists of the flora and the fauna from the specified valleys. This information displays the present-day status of the mentioned rivers and valleys, and may therefore be regarded as a basis for long-term ecological research and future environmental monitoring activities that highlight the trends of the changes. All this data is absolutely necessary in order to create field preservation projects for conservation purposes.

The Carpathian basin is in fact a transboundary region in which rivers are not aware of national borders. This fact demands unitary management measures realised in the future, and further transboundary research projects made by a group of scientists from both Hungary and Romania.

Conclusions

Maps showing the location and sizes of the natural, semi-natural, and degraded (polluted) sectors of the rivers and their valleys have been plotted based on the physico-chemical, pedological, botanical and zoological studies (see cover picture to this volume). The most significant species and communities, which can serve as bioindicators, have been identified. At the same time, scientists have researched the particularly valuable territories, specific to the Carpathian basin and the endemic or rare elements of the flora and fauna in order to identify the land surfaces that require special conservation measures. For the Criş Rivers Basin we have proposed a Red List, that can be extended in the future to include the rest of the hydrographical basins.

The characteristics and problems of the studied rivers are as follows:

1. The construction of the dam-lakes in the valleys of these rivers modifies most of the environmental aspects of these regions. Unregulated tourism and the construction of cottages has also had a disastrous effect.

2. In most of the cases, woodcutting is intense in the spring sectors, and the wood-processing waste treatment is done irresponsibly.

3. Only a few patches of forest still exist in the middle and lower sections (except the valley of the Mureş), where large agricultural crops lie in the immediate vicinity of the river. There are thus very few trees, and the existing groves have been cut. The riverbanks are neglected. There is a lot of illegal waste accumulation. In addition, there have also been some cases where dumping grounds from the urban areas have been placed on the riverside right next to the riverbed. In these sectors, gravel and sand exploitation is intense, oil pollution occurs due to mismanagement of exploitation-machines.

4. In the lower sectors the dams are too close to the riverbed so the flood-areas are missing.

5. The non-ferrous metal exploitation and ore-processing drastically pollute the spring sector of Someşul Mare and the river sector downstream to the town Baia-Mare.

6. The communal and industrial sewage-production of the big towns and industrial establishments is so intense that, in some sectors, it has destroyed the formerly existing communities. Some species have disappeared completely.

7. The segmental pollution isolates the local populations, fragmenting the once continuous area. The disappearance of local populations decreased the intraspecific diversity, since, in most of the cases, typical ecological forms have disappeared.

8. The rivers provide many settlements with drinking water, but because of the high pollution level it is now unfit for human consumption. There is therefore an urgent need for the construction of efficient sewage-treatment plants that are ecologically sound.

9. Many valuable wild areas in the valleys of these rivers need increased protection, such as: "Cetatea Rădesei - Bazarul Someşului Cald" Strait, the peat-bogs from the upper section of the Someşul Rece, the "Fânaţele Clujului" reservation, the "Sic-Săcălaia" lake, the "Suatu" reservation, the spring-region of the Someşul Mare, the lawns from Mogoşeni-Floreşti, and the meso-hygrophilous lawns from Benesat-Ardusat on the Someş; Vadu Crişului Strait, thermal springs at Răbăgani and Băile Episcopeşti, Cefa fish ponds and Rădvani wood on the Crişuri; the peat-bogs in the Gheorgheni Depression, Topliţa-Deda Strait, the 400 ha ***Populus nigra*** forest near Arad and the marsh from Bezdin on the Mureş.

10. The rivers only constitute an ecosystem when considered together with their respective flood-areas. The protection of the river and the valuable wild areas is unimaginable without reconstruction, such that the restoration of at least some of the wetlands from the catchment areas and that of the groves is realized. The "ecological corridor" created in this way should become an important link between the valuable strictly protected areas.

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Overview of the Long-Term Ecological Research Performed by GEOECOMAR in the Danube Delta, Romania

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Introduction

The Danube Delta is one of the main components of the Danube River system, and represents the natural interface between a vast drainage area (817,000 km^2) and the inland-receiving basin of the Black Sea. The delta is fluvially dominated, and shows a typical triangular shape, having 65 – 85 km distance from apex to coast and up to about 70 km width between the branches. This is the second largest deltaic area in Europe, after the Volga Delta, covering more than 4,150 km^2 of complex water systems and emerged land belts. There are about 3,500 km of natural streams and artificial canals, connecting more than 450 lakes, all these water bodies representing closely interacting ecosystems. A series of interdistributary depressions, with specific hydrographic networks consisting of interrelated systems of lakes and channels, may be outlined between the main Danube branches and south of the Sf. Gheorghe Branch. Two depressions (Sireasa and Pardina) have been wholly transformed in agricultural polders and their water systems include now only some artificial drainage canals. Southwards, there is the Razim – Sinoie lagoonal complex, a large lacustrine area (1,015 km^2) supplied with water and sediments from the Sf. Gheorghe Branch. Throughout this group of lakes can be observed a slow general water flow, from north to south, which at the end discharges to the Black Sea through the Periboina outlet, located in the southernmost part of the lacustrine complex. The depths of the deltaic and lagoonal lakes don't usually exceed 3.5 m.

The anthropogenic activities developed within the Danubian hydrographic basin, populated by 85 million inhabitants, made the Danube River the most important eutrophication and pollution source, both for the Black Sea and for the Danube Delta. The riverine influence and the human interference carried out inside the Danube Delta itself have disturbed the natural equilibrium of this highly dynamic, but particularly sensitive, assemblage of biocoenoses and ecosystems. There are only 15,000 inhabitants in the delta, but more than 300,000 people are living around the Danube Delta and Razim – Sinoie lacustrine complex, exerting an important anthropogenic pressure over the whole deltaic and lagoonal biome.

This study is an attempt to identify and outline some environmental problems and to provide a general evaluation of the current status and tendencies concerning sediment and water contamination in the Danube Delta, as was evidenced by the observations and analytical data obtained after the cruises organized by GEOECOMAR in 1995 - 1998. The main objectives are to assess the sediment and water quality, to obtain up-to-date information on contaminant sources and fluxes and to detect patterns and trends in contaminant input and dispersal within the Danube Delta water systems. A central goal is to identify the areas under stress by assessing the impact of the anthropogenic activity, in general, and of the Danube river, a major source of nutrients and mineral/organic contaminants, in particular, over the biogeochemistry of the main aquatic ecosystems.

The monitoring activities were done beginning in 1997 with investigations on biogenic gas emissions. The research work started in 1997, as part of an international project concerning the fluxes of greenhouse gases in the northwestern region of the Black Sea coastal zone. The main goals of the project were to record the emissions of selected greenhouse gases (N_2O, CH_4 and CO_2), to assess the current gas fluxes and the physical, chemical and biological changes across the Danube Delta, and to extrapolate the obtained data to similar areas around the Black Sea. The project was carried out under the INCO-Copernicus Programme and complemented previous and ongoing international projects such as EROS 2000, and EROS 21, devoted mainly to the Black Sea.

Materials and Methods

The field research activities carried out during the period 1995 – 1998 were organized in the framework of a monitoring program, using the same sampling network each year, in order to assess the spatio-temporal variability of selected lithological, physical, chemical and biological parameters. In 1998, the strategy of sample collection was changed, and the field activity focused on less numerous, but more representative aquatic ecosystems, which were investigated in detail. The whole sampling and measurements program has been achieved in various hydrological conditions, in 472 stations, during 8 sampling campaigns. Sediment, water and biota sampling was carried out within the main lakes and channels of the deltaic water systems, as well as within the Razim – Sinoie lagoonal complex. Beginning with September 1997, emissions of greenhouse gases (CO_2, CH_4 and N_2O) have been measured, using an up-to-date *in situ* gas analyzer. Three supplementary cruises have been performed during 1998, only for biogas studies, covering a large area, including the Ukrainian part of the Danube Delta, and a variety of hydrological and seasonal conditions. In this way, the study covered a spring period (May 11- June 3), with high water levels and medium temperature values (18-20^{o}C), a summer period (August 16-27), with low water levels and high temperature values (30-33^{o}C), and a cold autumn period (November 15-23), with increasing water levels and temperatures between 0 and 10^{o}C. The last campaign was devoted mainly to soil/air measurements. The biogas determination has been performed in fixed stations on land and in various lakes; when the local hydrological conditions permitted, longitudinal continuous profiles were carried out within some lakes and along numerous channels, including the main distributaries of the Danube Delta.

The sampling of bottom sediments was performed using Van Veen grabs and plastic corers. The samples were sub-sampled aboard for various types of analyses: grain size, mineralogy, chemistry, total organic carbon, magnetic susceptibility, radioactivity and benthic biota. Suspended mineral and organic particulate matter was collected by filtration and/or centrifugation. The obtained sediment samples were subsequently prepared and stored in specific conditions (refrigerated, oven dried), in view of future analyses.

The biologic samples have been collected using Van Veen grabs, bottom dredges and plankton nets. For phytoplankton analyses, water samples were stored and preserved with formaldehyde.

Surficial and bottom water samples have been obtained using plastic buckets and Nansen type bottles. Usually, composed and/or integrated surficial water samples have been collected from the lakes and along the channels, but individual samples were obtained as well, mainly from the bottom water. Selected samples have been vacuum-filtered on glass fiber (0.7 μm) and/or teflon filters (0.45 μm) and stored (refrigerated or treated with HNO_3) for mineral and organic pollutant analyses (heavy metals, ammonium, MBAS, pesticides). Bulk water samples have been also stored for heavy metals and total organic carbon analyses.

The gas measurements have been completed using a portable multi-gas monitor ("INNOVA" – Bruel & Kjaer type 1312) based on the photoacustic infrared detection method.

Main physico-chemical parameters (including nutrient concentrations) have been measured in situ, aboard, on raw and/or filtered water samples, using field equipment. Heavy metals, total organic carbon and pesticide concentrations in water and sediments, ammonium and chlorophyll in water, and grain size, mineralogy, magnetic susceptibility, chemistry and radionuclide contents of the sediments were determined in Bucharest and Constanta laboratories. Studies on planktonic and benthic populations have been achieved also in laboratories on land.

Results

Due to their particular position, the Danube Delta and the Razim – Sinoie lagoonal system may be considered as a natural filter, interacting between the Danubian inputs, rich in contaminants collected from a huge catchment area, and the western Black Sea region. Most of the water is entering the deltaic area between March and July (60%), via the magistral channels, through levee crevasses, or over the riverbanks. During these spring floods, important supplies of suspended load sink behind the levees and are filtered through the developing fen vegetation, being trapped and gradually sedimented in the backswamps, lakes and secondary channels. The modification of the water circulation inside the delta, produced by several channelisation phases, caused an artificially augmented water transfer and produced strong filling up processes in many lakes and channels, even if the solid discharge of the Danube decreased because of the damming works done upstream on the river. As a direct consequence, the role of environmental buffer played by the delta was seriously altered.

The cruises performed in the last four years provided a huge quantity of data concerning various aspects of the delta's environment quality and involved analyses of numerous physical, chemical and biological parameters. Since an exhaustive presentation of this information cannot be made, this presentation will focus only on the most important results gathered from the examination of some selected physical and geochemical parameters of sediment and water samples collected within the aquatic ecosystems of the Danube Delta and Razim - Sinoe lagoonal complex. A summary of biogas studies is also included. More details concerning sediments, water and biogas emissions from the Danube Delta will be presented in several specialized papers.

Quality of Sediments

The bottom sediments were investigated in detail only after the first cruise. The monitoring of their quality requires longer time intervals between successive determinations of various parameters (grain size, mineralogy, chemistry) in order to prove possible tendencies in their evolution. Suspended sediments have been also collected during several campaigns and analyzed for clay mineralogy (1/1995) and for chemical composition (3/1996), but only the bottom sediments will be presented now.

Lithology. The modern sediments of the Danube Delta lakes and channels show moderate variability, from mineral clayey - silty muds, consisting largely of allogenic silicate minerals of detrital origin, to more organic and/or calcareous muds, rich in authigenic components. Usually, the lakes influenced by more or less direct supplies from the Danube River (i.e. Lungu, Mesteru, Fortuna, Uzlina, Iacub) exhibit grey - blackish mineral muds, with soapy appearance, rich in bioturbations, showing a grey - yellowish (oxidized) fine and fluffy layer on top, containing mainly Unio, Anodonta, Dreissena and Viviparus shells and living specimens. Sometimes, fine sands and sandy muds are encountered in the channel-mouth fan areas. The lakes protected by direct riverine input (i.e. Baclanesti, Bogdaproste, Trei Ozere, Babina, Matita, Raducu, Isacova, Rosu) are characterized by black and grey - brownish to yellowish loose (porous) muds, which lacks cohesiveness, sometimes with saprogenic or hydrogen sulfide smell, very rich in authigenic calcium carbonate, coprogenic and vegetal organic matter, at places with reed fragments and rare shells and living mollusks (Anodonta, Unio, Viviparus etc.). There are also numerous lakes with intermediate conditions (i.e. Cutetchi, Tataru, Durnoi, Puiu) and intermediate sediments.

The active channels contain sands and sandy muds when are directly connected with the main branches of the delta (Mila 36, Crisan, Dunavat, Dranov), and show commonly heterogeneous deposits consisting of shells, living mollusks, vegetal (wood) fragments and grey - blackish sandy - muddy matrix, when are farther of the riverine inputs (i.e. Litcov, Isac, Sontea).

The Razim - Sinoe lagoonal complex contains generally grey - blackish silty muds, oxidized and non-cohesive on top, with large bioturbations, showing usually at about 10 cm under water/sediment interface a shelly layer (5 - 10 cm) consisting almost exclusively of Cardiida shells and shell fragments. Sandy bottom sediments are common for the peripheral parts of the Lake Sinoe. Mainly Anodonta and Unio sp represent living mollusks. In the lakes Razim and Golovita and Corbula sp. In the Lake Sinoe. Mya arenaria shells are very widespread along the eastern side of the Lake Sinoe.

Grain size. Granulometric composition of the Danube Delta sediments pointed out the prevalence of silty and silty-clayey sediments in about all lacustrine areas. Sandy deposits were identified mainly in channels, marking sometimes the channel-mouth fans in the lakes directly influenced by the Danube River loading (Mesteru, Lungu, Iacub, Puiu, Rosu), and superimposed on the beach ridges in lagoonal belts (Lake Sinoe).

Clay mineralogy. The clay mineral association is dominated by smectite and illite in comparable amounts (25 - 55%), followed by subordinate kaolinite and chlorite (5 - 15%). There is an evident mineralogical differentiation between the danubian inputs and the deltaic bottom sediments. The mineralogy of the Danube River suspended sediments is influenced by the seasonal hydrodynamic conditions, but the average smectite/illite ratio is commonly sub-unitary (S/I = 0.60 - 0.90). Instead, the bottom sediments of the farther deltaic lakes show increasing tendencies of smectite contents, leading to smectite dominated clay mineral associations (S/I = 0,98 - 1,38). The process of relative enrichment in smectite by differential transport and sedimentation was identified within the Danube Delta lake system and inside the Razim - Sinoe lacustrine area as well. The rather high contents of smectite suggest the importance of adsorption phenomena for transport and accumulation of heavy metals and organo-metallic compounds in sediments.

Magnetic susceptibility. Usually, the mineral muds show higher magnetic susceptibility, well correlated with the riverine sediment input. All the lacustrine areas evidenced on LANDSAT imagery as receiving elevated amounts of suspended silt have been identified as containing bottom sediments with high magnetic susceptibility. A special case is represented by the sediments of the Lake Dranov, protected from direct Danubian supplies, where relative high magnetic susceptibility values may be induced by a certain level of pollution, proved by chemical composition, as well.

Chemical composition. The distribution of some selected major elements (**Al**, **Fe**, **Ca**) and of the total organic carbon (**TOC**) within the bottom sediments of the Danube Delta correlates very well to their lithological and grain size constitution.

Al_2O_3 and Fe_2O_3 show the highest contents in clayey - silty mineral muds from lacustrine areas controlled by more or less direct inputs from the Danube River (i.e. Mesteru - Fortuna and Gorgova - Uzlina depressions, Razim - Sinoe complex). Clay minerals and Fe oxides and hydroxides have an important adsorption potential for heavy metals and other polluting compounds. Thus, both Al_2O_3 and Fe_2O_3 exhibit strong positive correlation to various heavy metals. Al_2O_3 represents a proxy for the grain size variation of the aluminosilicate minerals, particularly the clay fraction of the sediments, so it has been used for reference metal normalization.

CaO** and **TOC are significant components mainly in the organic - calcareous muds, widespread within more sheltered areas, that are protected against direct riverine supplies (i.e. Matita - Merhei, Raducu - Raduculet and Lumina - Rosu depressions). These parameters show negative correlation coefficients with all heavy metals, even if the organic matter can concentrate some trace elements.

Heavy metals and other trace elements. The trace metals are incorporated in sediments in various forms, more or less mobile, interacting with the water and biota during and after transport and sedimentation. Anthropogenic contribution to the final or momentary composition of the sediments can lead sometimes to dangerous concentrations, exceeding the normal levels, specific for each watershed. At present, the natural background of the sediments provided by the Danube River basin is not well determined, so the evaluation of trace metal contamination of the Danube Delta sediments was carried out using the average natural concentrations estimated by *Turekian and Wedepohl (1961)* for shales, and French standards for the Rhone-Mediterranean-Corse basin (in *Naffrechoux, 1992)*. Normalization procedures, using Al_2O_3, TOC and clay contents have been applied, as well, in order to identify anomalous metal concentrations *(UNEP/IOC/IAEA, 1995*). Bottom sediments have been analyzed for **As**, **Ba**, **Cd**, **Cr**, **Cu**, **Hg**, **Mn**, **Ni**, **Pb**, **and Zn**, using ICP-MS techniques.

The trace elements contents show highest concentration in the mineral muds of the Danube influenced lakes, and correlate positively with Al_2O_3, Fe_2O_3 and magnetic susceptibility, and negatively with CaO and TOC, as a consequence of the abundance of clay minerals, iron oxides and hydroxides, whose retentive properties are very strong.

The concentrations of **Hg** and **Cd**, the only metals included on the *List I ("Black List")* of the Paris Convention and EC Directives (76/464/EEC) are not at dangerous levels. The other analyzed elements, **As, Ba, Cr, Cu, Mn, Ni, Pb** and **Zn,** classed as *List II ("Grey List")* substances, are not exceeding, usually, the "normal" values, but may show increasing trends in areas controlled by riverine inputs. Therefore, many lakes from Mesteru - Fortuna depressions, or Iacub, Uzlina and other lakes which receive important Danubian sediment supplies, show high contents in almost all trace elements. Consequently, the calcareous - organic muds from the Matita - Merhei depression and from other lakes with more confined conditions, are poor in trace metals.

Some increased values, showing suspect situations, were recorded for As, Cr, Ni, Mn in various sediments (mainly silty - clayey muds). In addition, the examination of the Al-normalized values for the same areas suggests that some of the elements (Cr, Ni, Mn) could have higher levels of natural abundance in Danubian sediments than the French standards, so the state of metal contamination could be reconsidered.

The distribution of trace elements in Razim - Sinoie lake system sometimes shows gradual increases of metal abundances from northern stations (lake Razim) to southern ones (lakes Golovita, Sinoie). It is the case for Ni, Cr, Zn, Cu, Cd, which could accumulate by differential transport and sedimentation, that the finest particles are transported and sedimented furthest from the source. This fine particulate matter, consisting of clay minerals associated with organic matter and hydrous oxides, have usually the highest adsorption capacity, and could therefore concentrate and transport high amounts of trace metals. Leaching of the tailing dumps of the flotation plant for Cu ores from Baia (1 km west of Lake Golovita), and atmospheric inputs from the same area, but also from southern industrial sources (Midia - Navodari), could be taken into consideration, as well.

Al-normalized values of various trace metals (Ni, Cr, Mn, and possibly Pb) show preferential concentrations in lakes with calcareous-organic muds, poor in clayey material: Cutetchi, Bogdaproste, Babina, Trei Ozere, Raducu, Rosu. Two possibilities might be considered: affinity for organic matter and/or atmospheric inputs, which are not related to clay mineral adsorption.

Quality of Water

The principal characteristics of the Danube Delta aquatic ecosystems are controlled by an association of natural and anthropogenic factors which induce sometimes important changes of the normal physical and chemical conditions of the water bodies and may lead to a differential dispersal of the pollutant load originated from the initial Danube River water input. The study of water quality has been achieved using various data sets of measurements, obtained in several campaigns, performed during different meteorological and hydrological conditions, which reflect the momentary situation of the water characteristics. The differences recorded during various cruises for some of the measured parameters are usual, but even then, some clear trends in water quality evolution within sundry morpho-hydrographical units were evidenced. For evaluation of water quality we used the five classes classification system, elaborated for the Danube riparian countries within the framework of the PHARE Project EU/AR/203/9, which try to harmonize the methods of monitoring and evaluation with those applied in the EC countries (Pinter, 1997).

A general outlook will be presented only for the parameters involved in evaluation of the aquatic environment quality. The use of the same sampling network during 1995 – 1997 campaigns allowed identifying seasonal changes and some trends in water quality evolution by analyzing the average values of various parameters in distinct periods and in different hydro-morphological units.

Sources and pathways of contaminants in the Danube Delta. Mainly the liquid and solid supplies from the Danube River control contaminant influxes within the aquatic deltaic environment. This is the main source and carrier of the major part of dangerous substances toward the interior of the delta, through its branches and the deltaic channel network. Sources of environmental degradation within the Danube Delta include navigation, agricultural activities in polders, and fish farm basins.

Around the Danube Delta, direct inputs of municipal and industrial waste waters from numerous rural and urban settlements, mining activities, surface erosion/runoff and ground water flows from large agricultural areas, untreated slurry discharges from pig-rearing farms etc. are to be considered. In this respect, the town of Tulcea, the Danube Delta water gate, represents the most dangerous point source, with huge plants for ferro-alloys and alumina, food factories and shipyards. Close to the Razim – Sinoie lagoonal complex, there is the flotation plant of Baia (1 km west of Lake Golovita), which processes Cu ores and holds three decantation dumps containing tailings rich in Cu, Zn, Cd, Fe. A second potential pollutant source is Midia – Navodari industrial platform (10 km south of Lake Sinoie) which includes refineries, plants for production of sulphuric acid and superphosphates. Here there are some dumps of phosphogypsum and pyritic cinders containing S, Pb, Cd, radionuclides. Atmospheric inputs of various pollutants provided by these industrial areas cannot be neglected.

General distribution of main parameters. The *spatial distribution* of various physical and chemical characteristics within the Danube Delta water systems points out some specific trends controlled by interrelated natural and anthropogenic factors. The areas directly influenced by the riverine inputs show generally normal levels for the physico-chemical parameters, but have increased concentrations of nutrients (except ammonium), Cr and Fe. This is the case for many lakes from the Mesteru – Fortuna Depression (Lungu, Mesteru, Fortuna) and certain lakes from other depressions (Uzlina, Iacub). More distant lakes and channels can follow a differentiated evolution. The most eutrophicated ecosystems, characterized by frequent algal blooms, exhibit higher oxygen concentrations, raised pH and decreasing nitrite, nitrate and phosphate levels, due to the nitrite oxidation and phytoplankton uptake. Other fairly isolated lakes or standing aquatic bodies that contain rich macrophyte vegetation and usually clear water (i.e. Cutetchi, Tataru, Baclanesti) are oxygen deficient and consequently preserve higher concentration of nitrites. The Razim – Sinoie complex, where the eutrophication phenomena are important, is characterized by high pH and oxygen concentration, increasing levels of conductivity, total dissolved solids, chloride and sulphates from north to south, following the water flow direction and the transition to a more brackish environment.

The dispersal of trace metals in the Danube Delta waters is controlled by various mechanisms. Fe and Cr show increased values in areas controlled by riverine inputs, pointing out their lithogenic origin. Mn, Zn, Pb show an irregular distribution, determined by lithogenic, organic matter or other influences. Mn, Zn and Cu concentrations decrease from the fluvial delta plain to the marine delta plain, suggesting a filtering mechanism. Some random distribution trends registered in areas situated inside the delta, could be fortuitous, generated by the temporal distance between different measurements, or might reflect atmospheric inputs. Regarding the trace metals in Razim – Sinoie waters, As and Mn show commonly lower average concentrations than in the deltaic lakes, while Cr, Fe, Ni, Pb and Zn are more abundant and can manifest increasing trends from north to south. Differential transport of particulate matter and/or the intervention of eolian pathway could be an explanation for the gradually increasing values registered southwards in the Razim – Sinoie lake system. The Baia and Midia-Navodari industrial sites mentioned above are to be taken into consideration.

A *vertical distribution* was evidenced in some lakes only for few parameters, when the atmospheric conditions were calm and the water mixing reduced. There is a general decreasing trend from surface to bottom waters for temperature, oxygen, pH and Eh; the conductivity and dissolved solids increase frequently bottomward, mainly during high water periods.

The cruises have been organized in various hydrological conditions and this fact allowed proving a *seasonal distribution* of the main parameters. The variability is a common fact for dynamic environments like river – delta systems even during the same water regime; therefore the temporal trends can de evidenced sometimes only by statistical evaluation. There are two main factors influencing the seasonal variability of some parameters: hydrologic regime and biologic activity. During the flood periods, mainly in the springtime, the riverine influxes are stronger, and can be perceived within the whole deltaic and lagoonal area. The nutrient contents are usually higher, and usually, decreasing tendencies can be evidenced as regards nutrient evolution, from the danubian input areas to the farther ones. In the summer and autumn time, when the water level is low, the algal blooms are widespread and the biological control becomes more important. Due to the phytoplankton action, the nitrites and nitrates are usually diminished, and the pH and the oxygen concentration of the surface waters are generally higher.

The *partitioning* of the trace elements between particulate and dissolved phases is generally influenced by various factors (riverine sources, atmospheric inputs, biological activity etc.). The distribution coefficients pointed out that As, Cr, Cu, Fe and Mn are preferentially included within the solid phases, Ni is present mainly in solution. Other elements show dual distributions: Pb is usually bound up with particulate material, except in the deltaic water systems during low water conditions, when the major part is dissolved; particulate Zn is dominant in solution during the floods, and as solid phase at low water levels during the dry seasons. In this respect, a Zn uptake by the developing phytoplankton could be considered, as was proved for Mn. Desorption processes could be supposed during the transport through the deltaic water systems for As, Cr, Fe, and from freshwater to brackish water within the lagoonal complex for As, Cr, Fe, Ni and Mn.

State of aquatic ecosystems. The differential transport and sedimentation of the particulate matter, adsorption and desorption phenomena, variation of the physico-chemical parameters, evaporation-crystallization processes, biological activity and the filtering role played by the complex deltaic water systems can influence the pollutant evolution and persistence in Danube Delta.

A first evaluation concerning the state of the Danube Delta aquatic environment, which was obtained after the first cruise organized in the framework of the EROS Programme in the Danube Delta in 1995, (Radan et al., 1997) is confirmed and completed by the investigations carried out during the following campaigns performed until 1998. A general overview on the pollution state of the Danube Delta, as results from this data set, shows only moderate to small degradation of the ecosystems. The general distribution and the common tendencies put in evidence for various parameters allow drawing several conclusions concerning the distribution of contaminants in the Danube Delta.

The *physical-chemical* state of the Danube Delta water shows generally normal values concerning O_2 concentrations, conductivity, dissolved solid concentrations, Eh and pH. The oxygen concentrations are controlled by various factors (hydrological conditions, phytoplankton, macrophyte vegetation, sediment type, water depth, seasonal parameters etc.) which can induce variable distribution patterns within lacustrine water bodies. Some very low oxygen levels, close to anoxic conditions, have been observed at the bottom of some lakes (Cutetchi, Baclanesti, Tataru) and channels (Sireasa, Sontea, Lopatna, Magearu, Litcov, Isac 2, Perivolovca, Caraorman) with locally stagnant and/or confined water bodies, and are generally not directly connected to the recent anthropogenic activities. The highest pH values characterize the Lake Dranov and the Razim – Sinoie lacustrine complex. Suspended solid contents are influenced both by mineral particulate matter inputs of riverine origin, and by phytoplankton blooms. Anomalous concentrations of sulphate and chloride and, consequently, very high conductivity and total dissolved solids were found in Lake Dranov. Higher values of these parameters in the southern area of the lagoonal complex are naturally justified.

The *nutrients* are transient compounds through a very dynamic environment – Danube Delta; thus the range of their concentrations shows high spatial and temporal variability. These concentrations generally consist of low or normal values for nitrites and nitrates and usually higher values for phosphates. Values exceeding 0.100 mg/l for nitrites and 5 mg/l for nitrates have been usually found within areas controlled by direct Danubian inputs or situated near agricultural lands. The ammonium and phosphate evolution seems to be more influenced by local conditions: point sources (phosphate) and reducing environments (ammonium). Detergents containing phosphates may be discharged even from the boats. The high phosphate values measured in lakes Razim, Golovita and Sinoie, far from the direct riverine inputs, could be the effect of some point sources (pig-rearing farms, mining industry) located on the western border of the lacustrine complex. The strong eutrophication phenomena observed in numerous areas, including the lakes Razim – Sinoie, emphasize the impact of these nutrient inputs. Usually, the concentrations are lowered after the developing of spring and summer plankton blooms, following the utilization cycle of these nutritive compounds by phytoplankton.

The dispersal of *trace metals* in the Danube Delta waters is controlled mainly by riverine supplies, filtering mechanisms, including adsorption and desorption phenomena, and subordinately, by atmospheric inputs. The heavy metal concentrations infrequently exceed the EC environmental quality standards, but some distribution trends could suggest some potential dangers. The areas receiving direct water and sediment supplies from the Danube show generally increased concentrations for some elements (As, Cr, Fe, Mn), even if the normal limits are not exceeded. Some trace metals appear more concentrated in Lake Dranov (As, Ni, Pb, Zn, Fe), or in Razim – Sinoie lakes (Cr, Cu, Pb, Zn, Fe). As regards the lagoonal complex, some of the increased metal concentrations could be an effect of the leaching of waste dumps of the copper ore flotation station from Baia (close to Lake Golovita).

The areas, which cumulate the most anomalous parameters, and could be considered under stress, are the Mesteru – Fortuna depression, Lake Dranov and partly the lakes Golovita and Sinoie. Special attention must be paid to Lake Dranov, where most of the measured parameters show atypical values as compared with other lakes in the Danube Delta: low Eh, high pH, abnormal concentrations of $SO42^-$, Cl^-, and among the highest As, Cr, Ni, Pb, Zn, Mn and Fe abundance. The enrichment mechanism is natural, but the cause is anthropogenic: the Lake Dranov was isolated in the sixties and transformed in a semi-natural fishing pool. The evaporation-crystallization phenomena prevail, or are in equilibrium with the slight riverine inputs, and this prevalence leads to a dangerous salt content increase. Disappearance or diminution of valuable fish species has been observed in this lake.

Greenhouse gases emission

The greenhouse gases are generated by natural biochemical mechanisms taking place mainly in sediments, and also in the water column. The processes acting at the sediment/water interface, in the surface waters and at the air/water interface lead to important gas transfer to the atmosphere, if the specific level of saturation for each individual gas is exceeded by comparison with the water-air equilibrium. As it is well known, because of their specific biogeochemical characteristics, the deltas represent very important producers of biogases. Gas productivity of these areas and of other wetlands was amplified during the last decades because of the anthropogenic impact. The increase of the nutrient input, enhanced by human activities within the deltaic aquatic ecosystems, led to a continuous degradation of the natural environment, induced by the high productivity rate of phytoplankton, which intensifies the eutrophication phenomena, anoxia, nitrification and denitrification processes, and, among other consequences, an important increase of greenhouse gas emissions.

The initial phase (1997) of this project provided the first quantified evidence of the importance of the Danube Delta as producer of biogases. The field activities carried out afterwards, during 1998, have been focused on seasonal monitoring of greenhouse gas fluxes, and on the enlargement of the measurement network, in order to obtain a better knowledge of the temporal and spatial variation of the gaseous emissions. Four main cruises have been organized in various hydrological conditions (high and low water levels) and in different seasons (spring, summer, autumn). The results showed rather clear differences from place to place within the deltaic water systems, between emissions from the emerged vegetated areas and the wetlands, and between warm and cold seasons, etc.

Usually, the gas fluxes measured within water covered areas keep the same general trends (at different levels) each season, showing well outlined zones, controlled by organic matter and nutrients inputs in lakes and in main channels and branches. The evolution of gas concentrations and gas fluxes (Figure 1) along the main channels or branches of the Danube Delta is controlled by water inputs from interrelated aquatic ecosystems and by the seasonal conditions. The distribution patterns of gas fluxes values within the lacustrine areas show a clear link between the more productive zones, corresponding to the channel-mouth fans in the lakes (directly influenced by riverine loading), and the maximal areas of emission. The position of the measurement areas within the various morpho-hydrological units of the Danube Delta system is an important factor that controls the sediment characteristics and further, the gas production and fluxes. There are significant spatial variations both locally, in the same lake or channel, and regionally, as shown by the mean gas fluxes values. These lateral variations can be generally interpreted to be the result of complex biological, physical and chemical interactions. As concerns the general seasonal variations, all the determined biogas species showed maximal activity in spring and minimal in summer (Figure 2).

On vegetation covered areas, the most important factors influencing the gas fluxes, besides the environmental temperature, are the general water level within the Danube Delta, soil type and weather conditions. The presence or absence of a water layer contributes to add or not the diffusive transported gases inside of the water column which floods the vegetated zones, to the gases transported by vegetation. The gaseous emissions at soil/air interface show important seasonal variations. The N_2O production diminishes from spring to summer and to autumn, CO_2 is practically missing in spring and summer time (only daylight measurements), and CH_4 is maximal in summer, followed by spring emissions (Figure 2). Commonly, the atmospheric mixing ratios of N_2O and CO_2 within the Danube Delta are in accordance with the global measurements and the Black Sea area determinations, while the CH_4 level is significantly higher.

The water saturation in carbon dioxide is usually directly proportional with the methane saturation, and furthermore both gases indicate reverse proportionality with the dissolved nitrous oxide.

There are some variances between the biogenic gas concentrations in different regions or morpho-hydrographic units of the Danube Delta. The western depressions (e.g. Mesteru-Fortuna), more influenced by Danubian water inputs and by the agricultural land proximity, show higher concentration values than the eastern ones (e.g. Matita-Merhei, Lumina-Rosu). The distribution pattern of N_2O in Lake Razim presents maximal concentrations close to the entries of Dunavat and Dranov channels. Both cases point out the River Danube is a main source of nutrients and confirm the buffering effect of the Danube Delta. There are also some differences between channels and lakes. The channels are generally more concentrated in N_2O and even in CO_2 than are the lakes; further, the lakes are the most important producers of CH_4. A quite good positive correlation can be observed between CH_4 and CO_2 both in lakes and channels, and sometimes between N_2O and CH_4 in certain lakes. Usually, the northern lakes (located between Chilia and Sulina distributaries) contain the highest concentration values of greenhouse gases. The positive polynomial correlation CH_4/CO_2 is the most important in the northern lakes.

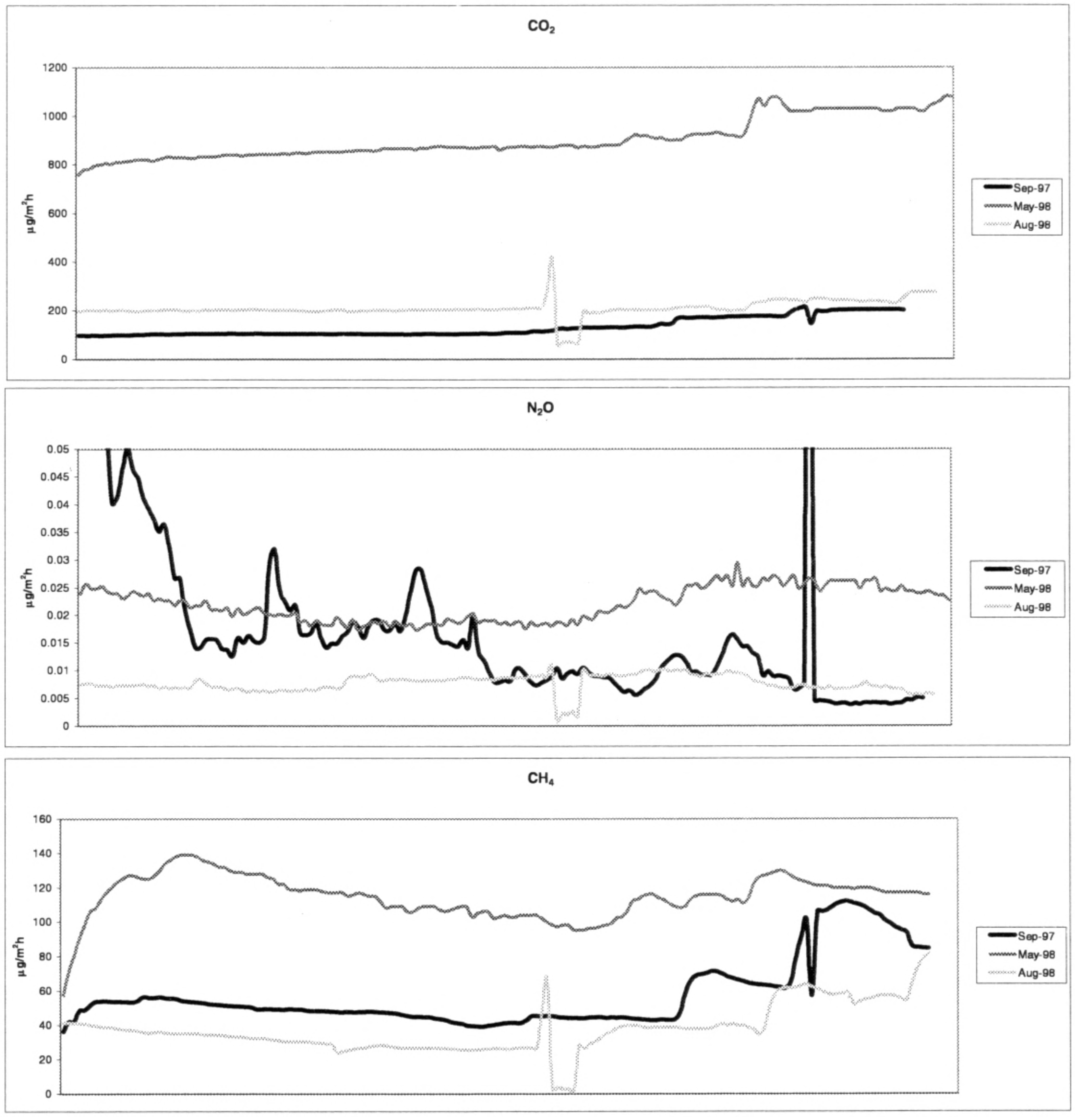

Figure 1. Evolution of greenhouse gas fluxes (mg/m^2/h) along the Sulina Branch (September, 1997; May, 1998; August, 1998).

A general outlook regarding the distribution of gas flux intensities all over the delta, including all the measured values, both on water and on land, suggest some peculiarities concerning the distribution patterns of the investigated gaseous emissions.

The N_2O fluxes are more intense in the springtime, showing numerous important emission “centers”, distributed all over the delta, but not far from the Danube branches. During the summer, the more active area is located within the central part, and in the autumn time, the emissions diminish and are concentrated in the upstream part of the delta, close to the Tulcea Branch. The seasonal decreasing importance of the nutrient inputs are quite well evidenced. This areal and seasonal pattern is controlled by the Danubian supplies, and by increased inputs of nutrients in the springtime, associated with denitrification processes developed in sediments. These processes are more intense in suboxic and anoxic conditions. In the summer the nutrients are used by macro- and microphytes and are subsequently trapped in sediments until the next spring.

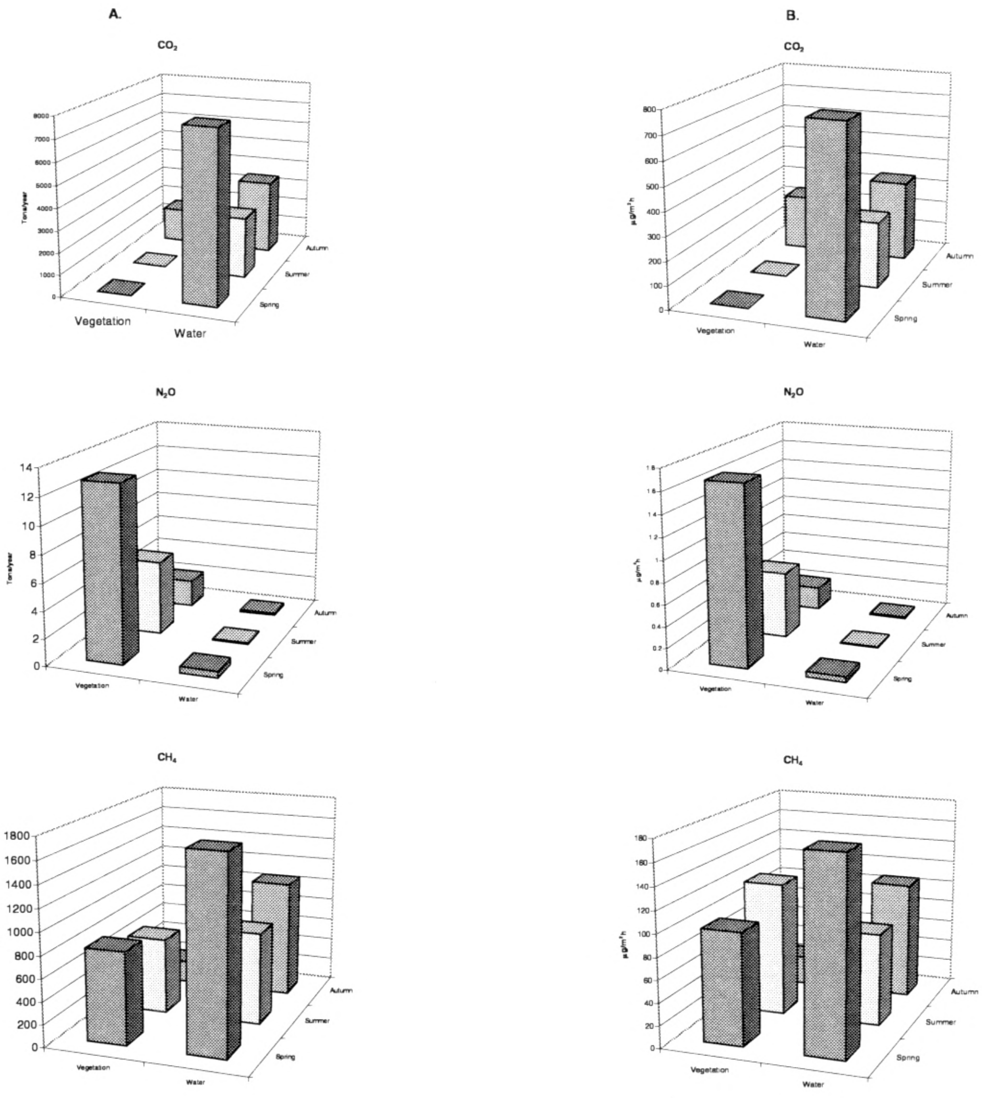

Figure 2. Seasonal evolution of total gas emissions (A) and mean gas fluxes (B) at soil/atmosphere and water/atmosphere interfaces.

The distribution of CO_2 fluxes shows a similar trend, with high intensities during the spring, concentrated mainly within the marine delta plain, and decreasing activity toward summer and autumn, when the more active areas move upstream. This pattern is influenced by the change in the oxygen regime under the influence of the strong algal blooms of summer and early autumn, together with the concomitant productivity increase. The temperature decrease can be also a restrictive factor for gaseous emissions.

The CH_4 emissions manifest more constant activity in time; the main centers seem to be more stable in space, due to the deeper location of the methanogenesis processes under the water/sediment interface. A general declining trend from spring to autumn can be observed, induced by the decreasing temperatures.

A first evaluation of the total gas emissions pointed out the water ecosystems as main generators of CO_2 and CH_4, and the land areas, covered with vegetation, the principal producer of N_2O (Figure 2). The total amounts of biogases provided by the Danube Delta could be evaluated at 15,565 tons/year of carbon dioxide, 21.228 tons/year of nitrous oxide and 5324 tons/year of methane (Table 1). These values are only informative estimations; more precise data will be obtained after several seasonal campaigns, including day and night measurements, and covering a more complete observation network. Even then, the complexity of the deltaic territory will limit the possibilities of a very accurate computation.

Table 1. Total gas emissions from Danube Delta.

Soil Type	Spring			Summer			Autumn		
	CO_2	N_2O	CH_4	CO_2	N_2O	CH_4	CO_2	N_2O	CH_4
Vegetation (Tons/year)									
S-Ft	0	1.38	22.5	0	1.05	43.2	-	0.23	62.5
S-F	0	1.99	308	0	0.23	17.8	80.5	0.11	0
SP	0	0.089	4.74	0	0.026	0.43	16.2	0.0013	0
SR	0	2.01	172.8	0	2.63	344.2	402.5	0.34	47.3
S-Pa	0	1.2	39.5	0	0.11	12.6	348	0.27	25.4
S-N	0	0.48	26.5	0	0.28	239.8	-	-	-
Ss-Ps	0	0.043	3.23	0	0.006	4.11	3.24	0.0069	0.73
S-Ps	0	4.74	234.1	0	1.18	16.9	751	1.11	65.4
PS	0	0.98	11.3	0	-	-	-	-	-
Total	*0*	*12.912*	*822.67*	*0*	*5.512*	*679.04*	*1601.4*	*2.0682*	*201.33*
General annual fluxes from vegetated soils (Tons)							**1601.4**	**20.5**	**1703**
Water (Tons/year)									
Total	7775	0.485	1734	2777	0.0983	826	3412	0.145	1061
General annual fluxes from water covered areas (Tons)							**13964**	**0.728**	**3621**
Total Gas emissions from Danube Delta in one year (Tons)							***15565***	***21.228***	***5324***

Legend:

S-Pa = *flavescens* reed vegetation on acid and/or salinized peat soil
SR = *flavescens* reed vegetation with sedges
N-S = *gigantea* reed vegetation on sandy soil
S-Ps = *gigantea* reed vegetation on compact peat soil
S-F = *gigantea* reed vegetation on fluviatile soil
S-Ft = *gigantea* reed vegetation on peaty fluviatile soil
Ss-Ps = *gigantea* reed vegetation with trees on compact peat soil
SP = reed vegetation with reedmace
PS = reedmace vegetation with reed

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Long-Term Productivity Forest and Grassland Studies in Ukrainian Carpathians

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Long-term productivity studies in the Ukrainian Carpathians were conducted in primary beech (*Fagus sylvatica* L.), spruce (*Picea abies* (L) Karst.), oak (*Quercus robur* L) forests, and secondary spruce forests, and also in subalpine and alpine meadows. Beech forest ecosystems were studied in Beskids (four permanent sampling areas in the Skole forest region at the altitude of 560-610 m a. s. l. on cambisols over the Carpathian flish in 33, 48, 75 and 100 years old pure beech forest stands). Oak forests were studied in the Carpathian hills (sampling area at the altitude 330-360 m a. s. l. on the soddy podzolic soils in 33, 54, 75 and 106 years old stands). The spruce study area was situated in the primary 35, 50, 80 and 120 years old forests in Chornogora (at the 1200-1400 m.a.s.l.) and in 35, 51, and 70 years old secondary spruce forest in Beskids and Gorgans (at 600-800 m.a.s.l.).

The analyses were performed inside the 2000 m^2 (40 m x 50 m) plots. The number of trees was counted within each plot. Every tree was numbered for easy identification. The breast height (1.3 m above ground on the uphill side of the tree) was permanently marked around each trunk with a point. The trunk diameter at breast height (d. b. h. in cm) was measured with a steel diameter tape exactly along the point mark.

Eighteen test trees were chosen to represent the range of different diameters and heights for each sampling area. Those trees were cut at the end of vegetation period (August-September) in the close neighbourhood of the plots. The stem was divided into 1 m logs, which were weighed. Test discs 5 cm thick, were cut at the base of each log for annual ring analysis. Different fractions of above-ground mass (branches, leaves, fruits) were analyzed according to Utkin (1975).

The determination of below-ground mass was carried out on trees of different diameter from each sampling area (Utkin, 1975, Lochmus and Oja, 1983). Roots of three trees were dug out and collected in groups of the diameter of below 0.5, 0.5-1.0, 1.0-5.0, 5.0-10.0, and over 10.0 mm.

In the Ukrainian Carpathians beech forest ecosystems have been found a high total biomass stock (617 t/ha in 100 years old forest) and a high annual increment of biomass of 15.4 t/ha/year in absolute dry weight. The mass of perennial organs (stems, branches, and large roots) increases with age, while the mass of leaves and thin roots does not change. The direct correlation between the mass of thin roots and mass of leaves did not depend on the age of forests (Kozak and Holubets, 1996).

Spruce forests were more productive compared with primary beech communities only up to the age of 30-35 years. After 35 years the increment in beech stands was higher than in spruce stands. Biomass of 56 years old natural beech was 372.0 t/ha and of 51 years old planted spruce stand was 195.5 t/ha. The annual increment of biomass in beech forest equaled to 17.2 t/ha/year and in spruce stands only to 9.9 t/ha/year. The replacement of primary beech forests by planted spruce stands is not justified at the area of the Ukrainian Carpathians (Kozak, 1990).

Oak forests did not reveal high accumulation of organic matter. On the basis of data on structure and productivity of oak forests of different age (33, 54, 75, 106 year old), biomass fluctuation in the range of 120.5-239.8 t/ha were studied. Mass of stems and roots changed within the range of 66.9-146.55 and 27.9- 45.4 t/ha respectively. The main part of this mass was accumulated in stems (from 56% in 33 year old forest stand to 61% in 106 year old stand). Nineteen percent of biomass in 33 year old stand and 23% in the 106 year stand was accumulated in roots. The total above ground plant mass surface was 104-164 thousand m^2/ha.

In the meadow of the Ukrainian Carpathians the primary production was 4.6 t/ha (43% above and 57% below-ground parts) within the forest zone and 1.7-2.4 t/ha at the timberline. A more detailed study of biomass and NPP of subalpine and alpine meadows was at the Pozyzevska 1 km^2 research polygon in the Chornogora (Malynowskij, 1984).

A method of modelling forest communities (GAP Model) was used for the description of dynamics of forests in the Ukrainian Carpathians (Menshutkin and Kozak, 1996). The models were verified according to field observations (Kozak, 1990). Forest dynamics were forecasted for next 600 years.

The model was used for quantitative estimates of the effects of various factors (logging, climate changes, introduction of new tree species) on dynamics of forest communities. Any results obtained through simulation modelling, however, need to be verified by long-term field observations and experiments.

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Effect of Forest Health on Biodiversity with Emphasis on Air Pollution in the Carpathian Mountains

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Abstract

The vegetation of the Slovakian Carpathians is altitudinally zonated. The lowest foothill zone (300-500 m a.s.l.) is characterised by oak and hornbeam forest stands. The lower montane zone is dominated by beech forests with admixture of fir. The upper montane zone is dominated by spruce. In higher ranges (e.g. Tatry Mountains) dwarf mountain pine, subalpine, alpine and subnival zones occur. In Slovakian Eastern Carpathians the timberline is formed by beech.

In the framework of the international project "Effect of Forests Health on Biodiversity with Emphasis on Air Pollution in the Carpathian Mountains" are included the following objectives: 1) to establish a network of biological monitoring sites along with the air pollution monitoring sites, 2) to evaluate responses of bark beetle populations to disturbance interactions related to environmental stresses with emphasis on air pollution, 3) to determine impacts of long-term pollution loading on genetic diversity of mountain forest ecosystems, 4) to examine the effects of environmental stresses on selected plant and animal indicators and 5) to use Geographic Information Systems (GIS) for spatial presentation of the air pollution and biological information.

The monitoring sites in the framework of this project are in the following localities: Geldek - Častá (Malé Karpaty Mts), Vrátna dolina - Štefanová (Malá Fatra Mts), and Biely Váh - Východná (Kozie chrbty Mts). The locality of the Malé Karpaty Mts - Geldek represents a protected landscape area. This monitoring site is located at the altitude 670 m a.s.l., on a SW slope; it is formed by Triassic dolomites, dark grey and grey limestones. Soils are represented by brown soils. The dominant tree species is *Fagus sylvatica*, which covers 87% of the site. *Fraxinus sp.*, *Acer pseudoplatanus* and *Tilia sp.* occur in admixture. The forest stand is represented by old (120 years) trees for which the health status is very good. The site in the Malá Fatra Mts - Štefanová, is located in the National Park. This monitoring site is at the altitude of 730 m a.s.l., on a N-NE steep slope (25%). It is formed by sandstones and shales with brown Rendzina soils. The dominant tree species is *Picea abies*. *Fagus sylvatica*, *Abies alba* and *Fraxinus sp.* occur in admixture. The age of the forest stand is 40-60 years. The health status of the site is very good. Kozie chrbty Mts - Východná is located in a protective zone of the Nízke Tatry National Park. It is located at the altitude 775 m a.s.l. on a steep (25%) N-NE slope. This site is formed by Triassic shales and fine-grained sandstones, and soils represent brown Rendzina type. The dominant species is *Picea abies*. *Fagus sylvatica*, *Abies alba* and *Sorbus aucuparia* occur in admixture.

The air pollution in the region is directly reflected in the health status of forest trees and their stands. Healthy forest trees are characterized by good growth, high degree of leafage and positive growth features. Stands formed by healthy individuals usually have well closed canopies. While the stands have not been formed by man to monocultures or man has not changed their tree species composition, these "healthy stands" are characterized also by natural tree species composition. They are not equally old and they are able to self-regenerate in a natural way.

Since the tree species are permanently under the influence of negative phenomena of air pollution, their health status is worsening. The first manifestation is the loss of leaves, decrease in canopy density, and reduced production of seeds. Air pollution also causes the reduction of potential for self-regeneration. In these stands appear a openings in

the canopy. This enables the penetration of the species requiring more light and higher temperature into the herbaceous layer. At the same time these species often have features which prevent the regeneration of forest tree species from the seeds of old stands.

These changes in the forest stands of the Western Carpathians Mts. are studied within the framework of the international project "Influence of forest health on biodiversity with emphasis on air pollution in the Carpathian Mountains" in which take part the research centres of Austria, Czech Republic, Poland, Slovakia, Ukraine, Roumania and USA. The project began in 1997 and it will continue up to 2000. There have been elaborated the results from field investigation on selected sites connected with the project in "Evaluation of air pollution by ozone and its phytotoxic potential in the Carpathian forests". On each of the selected sites were marked five permanent research plots on which were carried out complex phytocoenological investigations. Emphasis was put on the determination of the occurrence of all plant species (trees, shrubs, mosses), their number and cover. During the year there are investigated the changes of chosen properties of communities with an emphasis on the status and changes of biodiversity.

The results obtained in this investigation are preliminary ones. They are under PC elaboration and evaluation. Because the given experiment needs are ongoing, the summary results can be evaluated only after the first stage, i.e. at the end of the year 2000.

Evaluation of Ozone Air Pollution and its Phytotoxic Potential in the Carpathian Forests

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Abstract

High concentrations of ozone, exceeding the phytotoxic level, and high levels of nitrogen and sulfur deposition may have disastrous consequences for the biodiversity and stability of the Carpathian ecosystems. Protection against the deleterious effects of air pollution should become an essential component of the preservation policy in the Carpathian Mountains. It is necessary to establish a network of sites to monitor the air pollution systematically in the Carpathian arch to provide information on spatial and temporal distribution of ozone, sulfur dioxide and nitrogen dioxide concentrations. Results of the air pollution monitoring in conjuction with reliable and systematic forest health evaluation will provide the scientific basis for better understanding of causes of the continuing forest decline in the Carpathian Mountains.

In the framework of the international project "Evaluation of Ozone Air Pollution and its Phytotoxic Potential in the Carpathian Forests," a network of sites has been established to monitor the air pollution (O_3, SO_2, NO_2) and evaluate forest health in the Carpathian Mountains. This is a cooperative study involving the Czech Republic, Poland, Slovakia, Ukraine, Romania and the United States of America. The Project started in December 1996 and it will continue to December 1999. The objectives of this three year study is to establish spatial and temporal trends of ozone distribution in the Carpathian Mountains, to estimate incidence and severity of ozone injury to vegetation, and to evaluate a potential threat to biological resources.

Ozone, SO_2 and NO_2 concentrations have been measured by means of passive samplers during the growing season at the following localities: Vrátna dolina (Malá Fatra Mts), Geldek - Častá (Malé Karpaty Mts) and Biely Váh - Východná (Kozie Chrbty Mts). A Thermo Environmental Model 49 Ozone Analyzer and a Campbell Scientific Data Logger CR-10 were installed in July 1997 at the Research Station Východná. Measurement of ozone concentration was done during the growing seasons of 1997 (July - September) and 1998 (April - October). Results are preliminary. Measured data are being evaluated.

The ozone analyzer has operated during the growing season. Daily ozone concentration in 1997 fluctuated between 24,14 - 75,36 $\mu g.m^3$. In 1998 ozone values fluctuated between 10,19 - 87, 64 $\mu g.m^3$.

In both cases the emmission limits for the above-ground ozone proposed by the directive of EU 92/72 EEG for the protection of vegetation (limit is 60 $\mu g.m^3/24$ h) were exceeded. The maximum of one hour concentrations of ozone in 1997 was recorded at 141,43 $\mu g.m^3$ and they decreased to zero values. Zero values were recorded also in 1998. The maximum value of the ozone concentration was 160,61 $\mu g.m^3$. The above-ground ozone correlates with certain meteorological elements including temperature, cloudy weather and sun radiation. In our case probably the humidity and localization of the Research station Východná where the Ozone Analyzer is installed is significant. The month´s average values range from 31,45 $\mu g.m^3$ (September 1998) through 57,22 $\mu g.m^3$ (July 1997) to 62,13 $\mu g.m^3$ (May 1998).

The ozone assession by passive samplers was carried out in the sites in the Malé Karpaty, Malá Fatra and Kozie chrbty Mountains. In the Malé Karpaty Mountains the highest value was recorded in the second half of August at 111,51 $\mu g.m^3$ (1997) and at 130,12 $\mu g.m^3$ in the second half of July (1998). In the Malá Fatra Mts. the ozone concentration was lower than in the Malé Karpaty Mts. In 1998 the highest value was recorded in the first half of August at 124,77 $\mu g.m^3$ and in 1997 the maximum value was 83,93 $\mu g.m^3$ (in the second half of June). In the locality Kozie chrbty - Východná the highest ozone concentration was recorded in the second half of June 1997 - 63,97 $\mu g.m^3$ and in 1998 - 75,84 $\mu g.m^3$ also in the second half of June (Fig. 3-5).

The concentration for SO_2 and NO_2 measured by passive samplers in the mentioned localities were under the detectional limit.

Chemical Composition of Deciduous and Coniferous Vegetation, Mosses and Humus as an Indicator of Sustainable Forest Management in Slovakia

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Introduction

High concentrations of pollutants have resulted in large–scale forest dieback: 85% of forests in Slovakia exhibit symptoms of damage. Concentrations of 26 elements in foliage, and signs of injury in different forest tree species, foliage, and stomata, as well as differences in the content of elements in industrial areas, two National Parks, a military area, and heavy metal concentrations in the mosses (the difference 1991/95) and cover humus are presented.

Material and Methods

The foliage, mosses and cover humus were taken on monitoring plots from 3063 plots, in accordance with international methodology. The samples were taken by monitoring specialists in August 1995, and mosses were also sampled in August 1991. The accuracy of the analytical data published in this paper was verified and tested. The foliage was evaluated by scanning microscope JEOL 400 A and X–ray analyser LINK 10000. The particles deposited in the stomata of foliage (external content) were assessed as to their morphology and EDX spectra (Mankovská, 1996). The samples were evaluated by common statistical methods.

Results and Discussion

Total concentrations of the elements (mg. kg^{-1}) studied in the foliage, external element concentration (in %) in the stomata of foliage and literature values are given in Table 1. Total content of heavy metals in mosses, statistical comparison (1991/95), and cover humus is given in Table 2. The equilibrium of individual elements in plants is a precondition of their normal growth. Surprisingly, in contrast to data presented by Markert (1993), only highly positive correlation pairs ($r>0.9$) of locally emitted elements were found. External concentrations and higher standard deviations in industrial areas confirm an effect of polluted air. Defined PDT present 98.5 % acid, 1.2 % alkalic and 0.3 % ammonium type of 1.77 mil ha of forest lands.

Conclusion

Concentrations of elements are higher compared to literature values. More than 75 % of foliage surface contained Fe, Ca, Al, K. The highest values of Al, Ba, Be, F, K, Li were found in the vicinity of an aluminum plant; Co, Mg, Rb, V of an magnesite plant; As, Cu, Hg, S, Se, Zn in the region of non–ferrous metallurgy + mercury plant; Cd, Fe in the vicinity of a ferrous metallurgy plant; N, Sr from military area and Ca, Cr, Ni from the National Park Low Tatras. In comparison with the content of heavy metals excluding Cd– cover humus always contained more such elements than mosses. In comparison 1991/95 the content of Cd, Pb, Zn was reduced and the contents of Cr, Cu, Fe, Ni were increased.

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Table 1. Concentration of elements in the foliage of forest tree species on 3063 monitoring plots (in a network of 4x4 km, in $mg.kg^{-1}$)

Element	*Picea abies* Karst. mean (SD)	*Pinus sylvestris* L. mean (SD)	*Abies alba* L. mean (SD)	*Fagus sylvatica* L. mean (SD)	*Quercus sp.* mean (SD)	Total concentrations mean (SD)	External concentration %	Literature limit values
Al	116 (89)	280(194)	366(181)	119(84)	92(53)	151(139)	92.7	50–150
As	0.41(1.51)	1.21(3.58)	1.15(2.61)	0.68(1.44)	0.44(1.11)	0.57(1.69)	0.8	<0.2
Ba	53.2(43.8)	15.8(25.9)	35.6(23.9)	100(83.8)	82.3(51.9)	64.8(60.9)	0.5	<100
Be	0.010(0.035)	0.012(0.013)	0.012(0.013)	0.027(0.034)	0.029(0.064)	0.024(0.066)	–	<0.04
Ca	8078(5815)	5950(2498)	12774(642)	13534(7829)	12136(5182)	11021(8066)	93.4	4000–8000
Cd	0.19(0.16)	0.22(0.21)	0.26(0.17)	0.19(0.13)	0.12(0.11)	0.196(0.199)	–	<0.5
Co	0.16(0.16)	0.22(37)	0.24(019)	0.12(0.17)	0.17(0.16)	0.175(0.239)	–	<1.0
Cr	0.68(0.96)	0.59(37)	0.61(0.76)	1.06(2.89)	0.82(1.11)	0.795(1.7677)	1.6	<1.0
Cu	5.09(.81)	8.67(12.4)	8.15(7.12)	10.0(6.15)	9.30(13.6)	7.27(7.02)	0.4	6–14
F	6.28(4.15)	7.80(1.9)	8.34(5.07)	5.84(2.56)	4.74(2.10)	6.24(4.84)	–	<2
Fe	123(370)	146(111)	246(105)	216(1635)	131(79)	159(901)	94.4	200–2000
Hg	0.10(0.10)	0.15(0.40)	0.13(0.15)	0.11(0.11)	0.08(0.09)	0.10(0.13)	–	<0.06
K	6178(3209)	5609(1356)	5639(1487)	9504(2761)	9529(2093)	7503(3564)	78.5	5000–10000
Li	0.18(0.18)	0.19(0.25)	0.17(0.25)	0.16(0.14)	0.20(0.18)	0.18(0.19)	–	<0.5
Mg	966(479)	1161(422)	1088(455)	1892(771)	2003(890)	1458(1013)	48.9	1000–1500
Mn	977(783)	635(865)	1934(1636)	1026(970)	1650((1079)	1121(1060)	20.0	1000
N	16645(5221)	16631(5431)	17921(5470)	19754(6755)	20923(6170)	18165(6432)	–	18000–25000
Na	32.2(38.5)	42.7(57.1)	43.4(48.3)	58.5(28.2)	39.8(20.8)	42.0(41.3)	15.0	
Ni	2.60(2.45)	3.06(3.44)	3.80(2.38)	3.87(3.38)	4.28(3.08)	3.44(3.33)	6.8	1–2
Pb	1.73(2.70)	3.68(4.48)	2.61(3.06)	3.66(11.3)	1.80(3.85)	2.42(6.31)	–	2–6
Rb	10.2(10.0)	6.0(5.0)	6.1(7.3)	14.3(15.3)	10.5(7.5)	10.8(11.5)	–	<10
S	1959(851)	1952(1010)	2203(943)	2242(923)	2236(1088)	2163(1056)	0.4	1300–2000
Se	0.048(0.203)	0.069(0.046)	0.074(0.068)	0.058(0.043)	0.053(0.045)	0.06(0.15)	–	0.03
Sr	22.7(23.9)	10.0(35.4)	19.9(35.4)	29.3(20.3)	21.3(12.7)	25.85(25.61)	–	<10
V	0.94(3.20)	0.98(4.19)	1.03(2.10)	0.72(2.19)	0.44(1.10)	0.813(0.612)	16.1	<1
Zn	42.3(21.3)	57.7(43.8)	56.9(37.5)	41.0(46.5)	25.6(21.7)	42.7(34.9)	2.6	20–80
n	1114	105	178	574	126	3063	3063	
% of forest	26.8	7.7	5	29.1	11.3	100	100	

Note: mean – arithmetical mean; SD – standard deviation; n – number of samples; Total concentration – arithmetical mean element concentration in all forest tree species, External concentration of individual elements in the stomata foliage, literature limit values [(Bowen, 1979; Hunter, 1994; ICP, 1994; Innes, 1995; MARKERT, 1993) in Mankovská, 1996]; forest tree species % of total area 20 000 km^2 of forest in Slovakia.

Table 2. Concentration of heavy metals in mosses and humus in 1995 on 111 monitoring plots (in a network of 16x16 km (in $mg.kg^{-1}$)

Element	Mosses Mean (SD) 1991	Mosses Mean (SD) 1994	SE 1991/1994	Humus Mean (SD) 1994
Cd	1.37(0.78)	1.29(0.52)	0.665 N	1.14(0.16)
Cr	5.18(5.30)	16.9(14.6)	6.497 **	28.4(10.2)
Cu	20.6(11.5)	21.3(19.7)	0.260 N	19.6(34.9)
Fe	1878(1198)	1459(1735)	1.669 N	11825(6251)
Hg	–	0.22(0.72)	–	0.42(1.50)
Ni	2.21(1.60)	4.33(5.20)	3.737 **	21.2(11.5)
Pb	60.9(61.6)	30.6(25.2)	3.519 **	61.4(2.70)
V	–	1.87(3.50)	–	10.5(7.10)
Zn	173(87.3)	61.8(37.1)	11.241 **	108(56.4)

Note: mean – arithmetical mean; SD – standard deviation; n – number of samples; SE – statistical evaluation of differences of arithmetical means of element concentrations in mosses between 1991 and 1995 evaluated by t–test. N – unsignificant, ** P<0.01%, mosses (*Pleurozium schreberi, Hylocomium splendens, Dicranum sp.*)

Opportunities for Long-Term Ecological Research at the Tallgrass Prairie Preserve, Oklahoma

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The 150,000-hectare Tallgrass Prairie Preserve in Osage County, Oklahoma has been owned and managed by the Nature Conservancy, a private conservation organization, since 1989. The goal of the preserve is to restore a seminatural grazing and fire regime to a tallgrass prairie landscape. Although the preserve's mandate is conservation, the management can be thought of as a grand experiment in landscape ecology. Hence, there are ample opportunities for long-term research at the preserve.

Fire: the distribution of prescribed fires throughout the year is designed to mimic the prehistoric fire regime, with the majority of fires occurring during the dormant season (winter), but a sizable minority occurring at other times (Hamilton 1996). Burn sites are located using a randomization procedure. Although the target return interval is 5 years (i.e. 20% of the area burnt per year), the randomization procedure will insure that some areas will remain unburned for over a decade, while others may be re-burnt in relatively short succession.

Bison: 300 American bison were released to a portion of the preserve in 1993. The herd has since expanded to almost a thousand, and the bison area now covers a third of the preserve (with the eventual goal of covering almost the entire preserve; cattle are occupying the remaining land during the transition). The bison unit has (and will continue to have) no internal fences, allowing the bison to choose where they graze. Bison are ecologically quite different from cattle: their diet consists almost entirely of graminoids, and their wallowing and trails are more pronounced. Their shedding and horning behaviors have not yet been studied, but are likely to have strong effects on the landscape.

Monitoring of Vegetation: Ecologists often treat monitoring as a separate goal from investigative research, because in monitoring one does not have complete control of the treatments. Unfortunately, manipulative research often conflicts with the goals of nature conservation. However, it is possible to do investigative research without manipulation of nature, IF there are a large number of replicates, the 'treatments' have a reasonably high frequency, and if sites are studied over a long time scale. The best strategy is to have a large number of plots located objectively throughout the landscape. We have almost completed establishing a network of $100m^2$ plots at every intersection of the 1km UTM grid within the preserve. All plots will be resampled on 5-year intervals, although a random subset will be resampled annually.

The results to date have verified that there is a tremendous habitat diversity of the preserve, and that disturbance history, soil characteristics, and hydrology have important influences on vegetation. Although it is too early to evaluate the effects of the new fire and bison management on vegetation, preliminary analysis, the literature (e.g. Biondini et al. 1999), and casual observations reveal:

- Bison congregate on recently burned patches, and take advantage of the young growth of graminoids
- Heavy grazing on graminoids increases forb abundance
- Bison avoid forb-rich patches, and grasses then increase in the understory of the forbs
- Eventually such patches are burned, starting the cycle over again
- Species richness has increased over the past two years, with the exception of long-unburned plots.
- Heavy trampling by bison has allowed the persistence of ruderals, both native and exotic.

These results highlight the need for integrative long-term research including plant ecology, landscape ecology, animal behavior, soil science, and fire physics.

Although grasslands are the primary focus of research at the preserve, the preserve contains large stands of mature crosstimbers (*Quercus marilandica - Quercus stellata* forests). Despite the fact that crosstimbers cover much of Oklahoma, their dynamics are poorly known. Even the most basic questions of establishment, recruitment, growth and mortality have not yet been addressed in the literature. In 1998, we established a 200m x 200m permanent plot in which we mapped and tagged all trees greater than 2.5cm in diameter, a total of 7600 trees. Forest dynamics within this plot, in addition to replicates to be established in 2000, will be interesting to compare with those of oak forests worldwide.

Biodiversity patterns: The preserve is a complex landscape consisting of tallgrass prairie, shortgrass prairie, sandstone and limestone outcrops, savannas, and wetlands and forests of various kinds. This high habitat diversity is largely determined by geomorphology, but fire and grazing (and to a lesser degree, road building and the petroleum industry) have also played a strong role. Largely as a result of the habitat diversity, the number of vascular plant species (at least 740) is quite high. The fauna is less well known, but the richness of mammals, birds, reptiles, and butterflies is high.

There has been much interest in the determinants and consequences of diversity in grasslands (e.g. Klimeš 1995, Gigon and Leutert 1996, Tilman 1996, Zobel et al. 1996, van der Maarel and Sykes 1997). However, most research on this subject has focussed on very fine spatial scales. It is arguably the mesoscale (*sensu* Heikkinen 1996) of 0.1-100 km^2 that is important for conservation (Figure 1). Unfortunately, it is impossible to have a complete biodiversity survey at such scales, and we need to find methods for extrapolation (Palmer 1995). Fortunately, remotely-sensed images can be a tool to aid in such extrapolation.

We propose that the tallgrass prairie preserve, with its varied vegetation and reasonably well-known flora, is an ideal study system for developing models to estimate species diversity from remote imagery. If such models are successful, they can be tested in other systems, and eventually be used for creating biodiversity maps globally.

The key to understanding mesoscale diversity is habitat heterogeneity. One expects to find the most species where there are a variety of habitats present. The traditional way of assessing habitat heterogeneity from remotely sensed images is to classify spectral information into habitats. There are four main objections to this approach: 1) the classification of an image is itself arbitrary, because real classes grade continuously into each other, 2) if they grade continuously, some apparent habitat boundaries on a map will be real, while others will not, 3) for the classification to be useful, it must be rigorously ground-truthed, and 4) one cannot apply the results to other regions which might contain different habitats. To overcome these objections, we developed the *spectral variability hypothesis* (SVH). According to the SVH, species richness will be positively related to any objective measure (e.g. standard deviation) of the variation in the spectral characteristics of a remotely sensed image. Indeed, if we map variation in intensity (instead of the intensity itself), we see a map (Figure 2) of locations that are potentially 'botanically interesting' (e.g. savannas, edges of forests, wetlands, edges of ponds, roadsides, etc.). We propose to test whether such regions are indeed more botanically rich (at the mesoscale) than other sites. If so, we potentially have a major tool for predicting mesoscale diversity worldwide. The next phase would be to evaluate the SVH at ILTER network sites.

Other research projects (past and present) at the preserve have been quite diverse. These have included studies on the flora, fauna, microclimate, ecosystems, and anthropogenic impacts (Table 1).

Opportunities for research

Most of the projects listed above are not merely of local interest: indeed, they mirror similar research performed throughout the world. The Tallgrass Prairie Preserve has to offer the long-term researcher. The grasslands are dynamic and diverse, yet the vegetation and flora are well known. Although most of the preserve consists of native vegetation, there are a few highly-impacted sites where restoration ecology can be researched and implemented. An on-site herbarium is an aid to the identification of vascular plants. A many-layered GIS is being developed, and already includes burn and grazing history. There are many habitats to choose from, so it is possible to perform comparative research with other regions. The preserve is an ideal location for studying plant/animal interactions. Mammals of potential research interest include not only bison, but also beaver, deer, coyote, fox, and badger. There are comfortable accommodations at the preserve. The preserve is also relatively close to a major research university (Oklahoma State University). Although the facilities at the preserve are more than adequate for most field work, a major new research and teaching laboratory (with the capacity for additional lodging) is currently being planned. But perhaps most important, the tallgrass prairie preserve is a strikingly beautiful landscape, and an exciting place to do fieldwork.

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Table 1. A partial list of past and present research projects at the tallgrass prairie preserve.

The relationship between spectral variation and species richness
Bison behavior and diets
Diversity of lepidoptera
Soil seed banks of different habitats
Relationships between biophysical parameters and spectral data
Influence of bison fecal pats on vegetation
Bison choice of vegetation patches
Vegetation mapping using CAMS
Use of remotely sensed imagery to detect changes in species composition
Monitoring avian productivity and survivorship
Atmospheric radiation monitoring
The Oklahoma Mesonet
Effect of crude oil bioremediation on a prairie soil ecosystem
Disturbance effects on prairie streams
Effects of fire and ungulates on the diversity of prairie ponds
Leafhoppers of the tallgrass prairie
Effects of crown fires on crosstimber dynamics
Spatial patterns of crosstimber trees
Edge effects in forest patches
Land use history and forest cover
Factors affecting the survival and reproduction of the lesser prairie chicken
The population dynamics of *Echinacea pallida,* a prairie forb
A survey of the medicinal plants of the tallgrass prairie
Protein nutrition of small mammals of the tallgrass prairie
Seed dispersal by prairie mammals

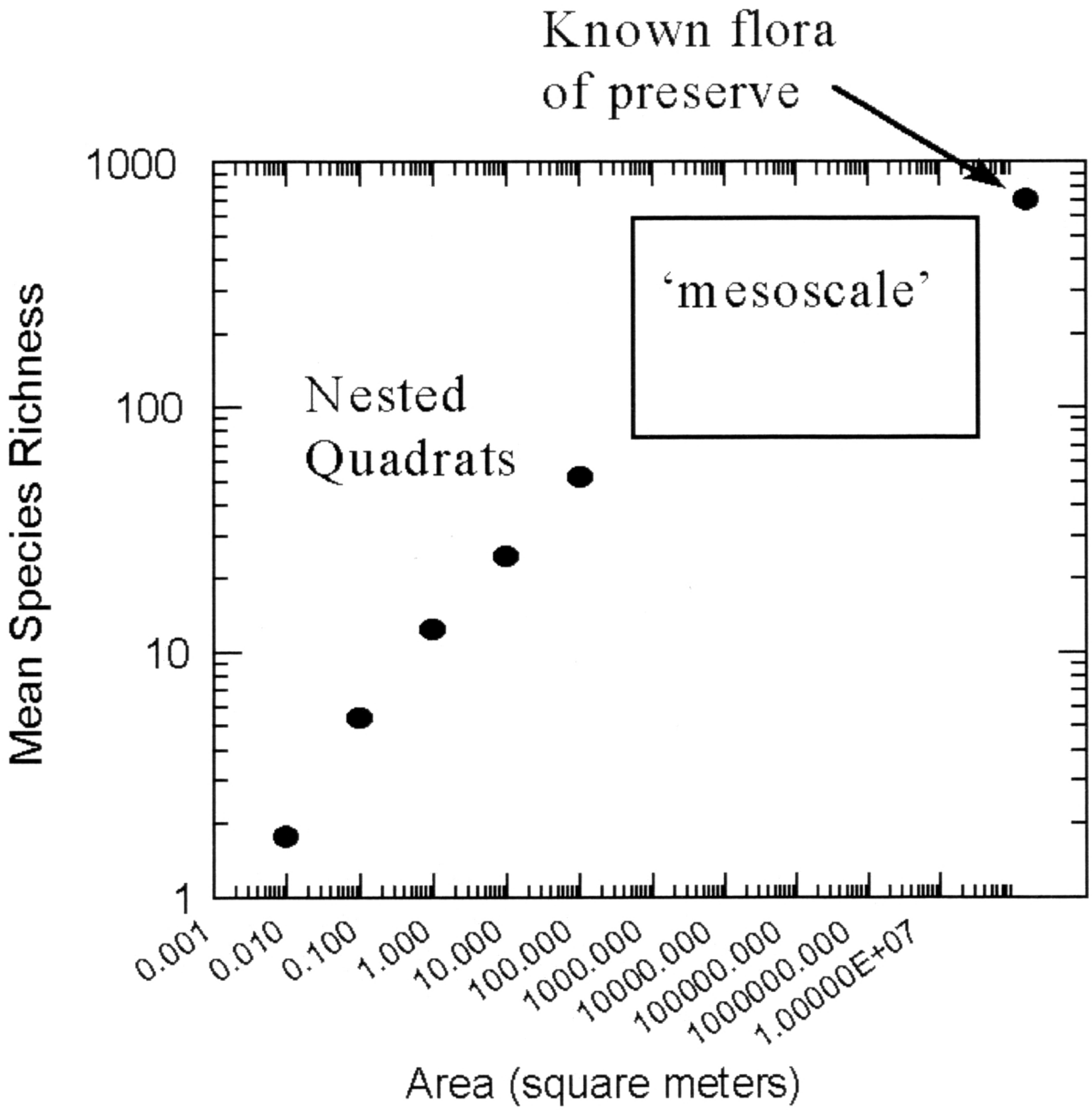

Figure 1. Species-area curve for vascular plants in the Tallgrass Prairie Preserve. The five data points on the left represent averages from 185 permanent 10m x 10m plots, each of which has a series of nested quadrats in each corner. The point on the far right represents the known flora of 740 species. The 'mesoscale' is a neglected aspect of biodiversity research, and will be the focus of future study at the preserve.

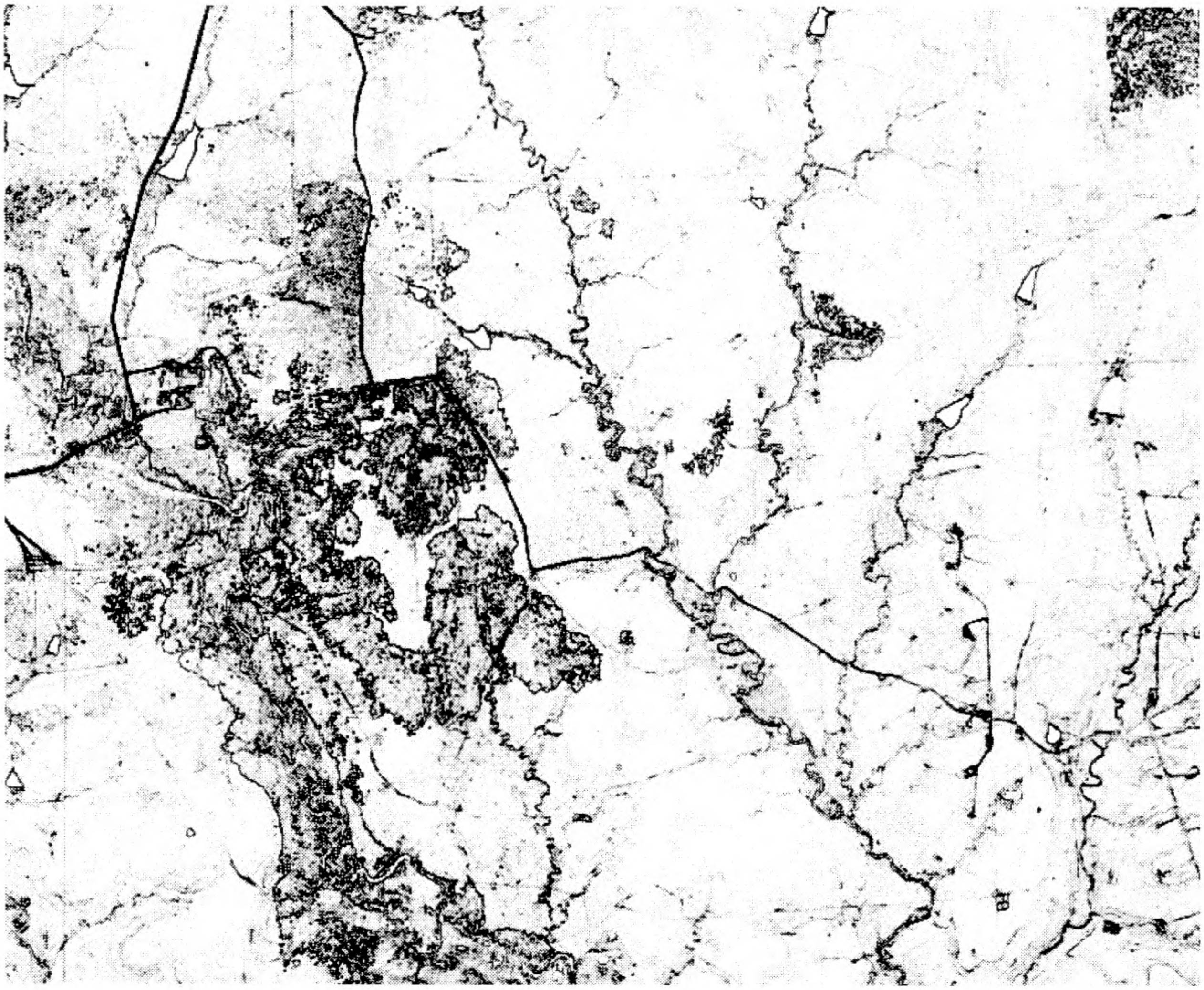

Figure 2. An image of a portion of the tallgrass prairie preserve. The darkness of the image is related to a measure of the spatial variation of reflectance (in other words, darker = more heterogeneous) of a digital aerial photograph, in which the pixels are approximately 1 meter on a side.