



**“NEEDS AND PRIORITIES FOR RESEARCH AND EDUCATION IN
BIOTECHNOLOGY APPLIED TO EMERGING ENVIRONMENTAL
CHALLENGES IN SEE COUNTRIES”**



Workshop Proceedings

NOVI SAD, SERBIA
2008

A CO-PUBLICATION OF THE
UNESCO-BRESCE, VENICE, ITALY,
AND
THE INSTITUTE OF LOWLAND FORESTRY
AND ENVIRONMENT, NOVI SAD, SERBIA

“NEEDS AND PRIORITIES FOR RESEARCH AND EDUCATION IN BIOTECHNOLOGY APPLIED TO EMERGING ENVIRONMENTAL CHALLENGES IN SEE COUNTRIES”

Edited by

Prof. Giuseppina Crescimanno, Ph.D, UNESCO-BRESCE, Italy
Prof. **Saša Orlović**, Ph.D, ILFE, Serbia
Rosanna Santesso, UNESCO-BRESCE, Italy
Leopold Poljaković Pajnik, M.Sc., Serbia

Editorial board

Giuseppina Crescimanno (Italy), **Saša Orlović**, (Serbia), Ivan Ts. Marinov
(Bulgaria), **Vladislava Galović**, (Serbia), **Tibor Tóth** (Hungary), **Željko Majstorović**
(Bosnia and Herzegovina), Ivan Blinkov (Former Yugoslav Republic of Macedonia),

Cover page:

Leopold Poljaković Pajnik, M.Sc.

Printed by:

Old Commerce, Novi Sad, Serbia

Disclaimer:

The authors are responsible for the choice and the presentation of the facts contained in this publication and for the opinions expressed therein, which are not necessarily those of UNESCO and do not commit the Organization.

The designations employed and the presentation of material throughout this publication do not imply the expression of any opinion whatsoever on the part of the UNESCO Secretariat concerning the legal status of any country, territory, city or area of their authorities, or concerning the delimitation of their frontiers or boundaries.

These papers have been published with the financial support of the UNESCO Office in Venice-BRESCE.

Table of Contents

Workshop background	4
Workshop programme	5
PAPERS PRESENTED DURING THE WORKSHOP	
<hr/>	
G. Crescimanno Linking Climate Change to Soil Protection for Developing Effective Mitigation Strategies and Policy Options	7
S. Orlovic, A. Pilipovic, V. Galovic, L. Poljakovic Pajnik, V. Vasic, P. Pap Harmonization of Demands in Agriculture, Forestry and Environment in Plain Part of Serbia – Problems, Solutions and Challenges	13
I. Blinkov, D. Mukaetov, O. Čukaliev Land Degradation in the Former Yugoslav Republic of Macedonia	17
Ž. Majstorović, S. Hodzić, N. Voljevica, D. Zulum Agrometeorological and Biometeorological Conditions in Bosnia and Herzegovina in the Last Ten Years	25
I. Ts. Marinov Ecological Challenges and Investigations in the Forest Fund of Bulgaria	33
A. Pilipovic, S. Orlovic, V. Galovic, L. Poljakovic Pajnik, Z. Galic, V. Vasic Environmental Application of Forest Tree Species in Phytoremediation and Reclamation	39
V. Galović, S. Orlović, A. Pilipović, V. Vasić, L. Poljaković Pajnik, Z. Galić The Role of Biotechnology in Creation Plants for Changed Environment	47
S. Kostadinov, N. Dragović, M. Todosijević Factors of Soil Degradation in Serbia	53
L. Letic, R. Savic, M. Velojic Wind Erosion Research and Monitoring in Vojvodina	61
M. Zlatić Necessity for Sustainable Utilisation of Soil and Water Resources	67
T. Toth Salt-Affected Soils in Hungary	75
<hr/>	



UNESCO Office in Venice-BRESCE, ITALY



INSTITUTE OF LOWLAND FORESTRY AND ENVIRONMENT, NOVI SAD, SERBIA

Building Capacity in Biotechnology for Research and Application in a Changing Environment

Background

The effects of climate change and increasing droughts are progressively becoming a major global issue. These effects are enhanced by rapid population growth and urbanization, resulting in problems associated with aquifer depletion, salt water intrusion and use of salt-compromised waters for irrigation, and enhancing land degradation. Chemical, physical and biological degradation, as well as their interrelationships, need to be considered in integrated programmes and approaches aimed at building capacity in biotechnology for research and application in a changing environment.

In many SEE countries, as well as in Serbia, there is an urgent need to develop research for development of appropriate biotechnology applied to the Environmental and to the Agro-forestry sector and to implement multidisciplinary approaches addressing the increasing environmental challenges, contributing to regional development.

The assessment of the needs and priorities in research and education to discuss strategies for developing biotechnology applied to environment and to involve policy makers and governmental authorities in the joint elaboration of action plans and national strategies are required.

To deal with all the above mentioned issues, UNESCO-BRESCE will create and coordinate a Working Group: **"Building capacity in biotechnology for research and application in a changing environment in SEE countries"**. This Working Group will involve scientists active in research and in educational programmes, students as well as decision makers and Authorities dealing with policy-relevant issues which are essential for economy and development of SEE countries.

The 1st meeting of this WG will focus on **"Needs and Priorities for Research and Education in Biotechnology applied to emerging Environmental challenges in SEE countries"** and was held in Novi Sad, from 8 to 10 July 2008. The meeting was organized by UNESCO-BRESCE in cooperation with the Institute of Lowland Forestry and Environment, Novi Sad, Serbia.

Expected results of the Workshop **were**: (i) establishing the Working Group for future actions, (ii) assessing needs and priorities in SEE countries, (iii) discussing and developing common strategies for application of biotechnology in environment.

The outcome of the Workshop will be published as proceedings by UNESCO-BRESCE in cooperation with the Institute of Lowland Forestry and Environment, Novi Sad, Serbia.

WORKSHOP PROGRAMME

1st Meeting of the Working Group on "Building capacity in Biotechnology for Research and application in a Changing Environment"

Workshop on: "Needs and Priorities for Research and Education in Biotechnology applied to emerging Environmental Challenges in SEE Countries"

Novi Sad, Serbia, July 8-10, 2008

Tuesday 8 July 2008

Morning: Arrival of participants

15:00 – 15:30 - Opening ceremony

15:30: 18:00 – 1st session*:

- Climate change, drought and risk of desertification in SEE countries (Topics: impact of climate change on physical, chemical, biological degradation, on risk of desertification, on society and economy)
- Serbia (Vojvodina Region) as a typical area needing environmental protection and management; possible benefits for economy, regional development
- Presentations and discussion in connection with this topic (e.g. other examples of areas in Serbia and in SEE countries needing attention or to be used as successful case-study)

18:00-19:00 - General discussion

Wednesday 9 July 2008

09:00-11:00 – 2nd session*:

- Developing capacity for research and education in biotechnology for a changing environment in SEE countries (Topics: novel techniques for plant breeding, selecting plant tolerant to drought, to salinity and other chemical hazards, novel methodologies for detecting chemical, physical and biological degradation and for phyto and bio-remediation; needs and priorities in higher education in relation to the topic (Ph.D Programmes needed; involving University students from SEE countries).
- Presentations and discussion in connection with successful case-studies and with situations needing urgent attention in SEE countries.

11:00-11:15 – coffee break

11:30-12:45 – 3rd Session*:

- Potential application of biotechnologies for environmental remediation and protection. Strategies and educational courses to be developed. Need for integrating results in Environmental plans and policies in SEE countries.
- Presentations and discussion in connection with the topic

13:00 – 14.00 break

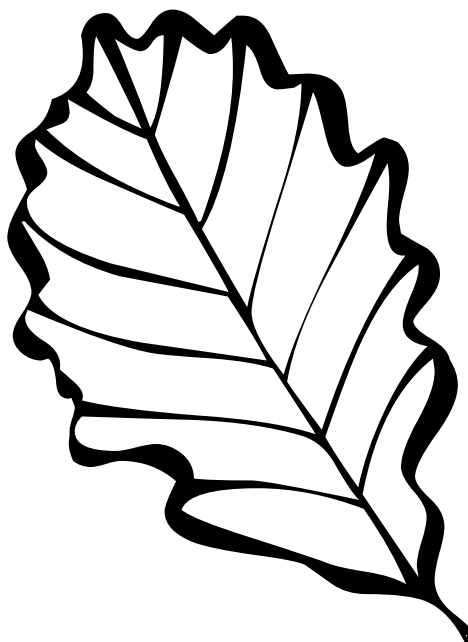
14:30–18:30 Discussion, Round Table with Authorities, addressing solutions and strategies for Environmental plans and policies in Serbia.

Thursday 10 July, 2008

08:00-13:00 – Technical tour in Vojvodina Region

13:00-14:00 –Lunch

14:00 – Departure of participants



LINKING CLIMATE CHANGE TO SOIL PROTECTION FOR DEVELOPING EFFECTIVE MITIGATION STRATEGIES AND POLICY OPTIONS

Prof. Giuseppina Crescimanno, Ph.D
Head, Science Section
UNESCO-BRESCE, Venice, Italy

Full Professor of Agricultural and Technical Hydrology,
University of Palermo, Italy

Summary : In many South East European (SEE) countries, as well as in Serbia, there is an urgent need to develop research for development of appropriate biotechnology applied to the environmental and to the agro-forestry sector and to implement multidisciplinary approaches addressing the increasing environmental challenges, contributing to regional development. To deal with all the above mentioned issues, UNESCO-BRESCE created a Working Group: "Building capacity in biotechnology for research and application in a changing environment in SEE countries". This Working Group will involve scientists active in research and in educational programmes, students as well as decision makers and authorities dealing with policy relevant issues which are essential for economy and development of SEE countries. Objectives and expected results of the Workshop "Needs and Priorities for Research and Education in Biotechnology applied to emerging Environmental Challenges in SEE Countries" are:

- establishing the Working Group for future actions,
- assessing needs and priorities in SEE countries,
- discussing and developing common strategies for application of biotechnology in environment.

The outcome of the Workshop will be the publication of its proceedings by UNESCO-BRESCE in cooperation with the Institute of Lowland Forestry and Environment, Novi Sad, Serbia.

Key words: Biotechnology, Environment, Climate change

INTRODUCTION

Effects of climate change and increasing droughts are progressively becoming a major global issue (Herrmann & Hutchinson, 2006). These effects are enhanced by rapid population growth and urbanization, resulting in problems associated with aquifer depletion, salt water intrusion and use of salt-compromised waters for irrigation, and enhancing land degradation. Chemical, physical and biological degradation, as well as their interrelationships, need to be considered in integrated programmes and approaches aimed at building capacity in biotechnology for research and application in a changing environment.

As a specialized agency of the United Nations, UNESCO contributes to the building of peace, the alleviation of poverty, sustainable development and intercultural dialogue through education, the sciences, culture, communication and information. To achieve UNESCO's and Member States' goals in the fields of science, the UNESCO Office in Venice - UNESCO Regional Bureau for Science and Culture in Europe (BRESCE)'s mandate consists in encouraging cooperation and providing specialized expertise within the European Region and the Mediterranean Basin and in implementing and sponsoring multidisciplinary and transdisciplinary activities in the fields of science. UNESCO-BRESCE's strategy is to assist countries under its mandate, i.e. SEE and Mediterranean countries, to enhance their capacity to deal with issues pertaining to environmental sustainability, including the formulation and implementation of policies for environmental management and protection and the use of applied research for environment and sustainable development.

There is an urgent need to develop research for development of appropriate biotechnology applied to the environmental and to the agro-forestry sector and to implement multidisciplinary approaches addressing the increasing environmental challenges, contributing to regional development. Assessment of the needs and priorities in research and education is therefore required in order to discuss strategies for developing biotechnology applied to environment and to involve policy makers and governmental authorities in the joint elaboration of action plans and national strategies.

To deal with all the above mentioned issues, UNESCO-BRESCE created and coordinated the Working Group: "*Building capacity in biotechnology for research and application in a changing environment in SEE countries*". This Working Group will progressively involve a larger number of scientists active in research and in educational programmes, students as well as decision makers and Authorities dealing with policy-relevant issues which are essential for economy and development of SEE countries.

The 1st meeting of this WG, which was held in Novi Sad, from 8 to 10 July 2008, focused on "*Needs and Priorities for Research and Education in Biotechnology applied to emerging Environmental challenges in SEE countries*". The meeting was organized by UNESCO-BRESCE in cooperation with the Institute of Lowland and Forestry, Novi Sad, Serbia.

Objectives of the Workshop were:

- (i) assessing the needs and priorities for research and education in biotechnology applied to emerging environmental challenges in SEE countries and
- (ii) discussing strategies and actions necessary for climate change mitigation taking into account achievements recently discussed during the Conference "**Climate change: Can soil make a difference?**" organized and hosted by Environment Directorate-General of the European Commission in Brussels on 12 June 2008.



Fig. 1. Start-up of the Workshop, Novi Sad, 8 July 2008

UNESCO'S STRATEGY AND PROGRAMME FOR 2008-2009

The 34th session of the UNESCO General Conference adopted the Medium-Term Strategy which **sets out the strategic vision and programmatic framework for UNESCO's action from 2008 to 2013** (Document 34 C/4). With respect to natural sciences, the overarching objective is mobilizing science knowledge and policy for sustainable development with the following three strategic programme objectives:

- Leveraging scientific knowledge for the benefit of the environment and the management of natural resources;
- Fostering policies and capacity-building in science, technology and innovation;
- Contributing to disaster preparedness and mitigation.

According to the document 34 C/5, defining the Programme and Budget for the 2008-2009 biennium, two Biennial sectoral priorities and four Main Lines of Actions (MLA) were established for 2008-2009, i.e.:

- Biennial sectoral priority 1: Promoting research and technical capacity-building for the sound management of natural resources and for disaster preparedness and mitigation;
- Biennial sectoral priority 2: Strengthening national and regional research and innovation systems, capacity-building, the use of technologies, and scientific networking, and encouraging the development and implementation of science, technology and innovation policies, for sustainable development and poverty eradication;
- MLA 1: Fostering policies, technical capacity-building, research, networking, education and international cooperation in the fields of water, ecological and earth sciences for enhancing societal responses;
- MLA 2: Oceans and coastal zones: improving governance and fostering intergovernmental cooperation through ocean sciences and services;
- MLA 3: Promoting science, knowledge and education for disaster preparedness and mitigation, and enhancing national and regional coping capacities, including through support for the development of risk reduction networks and monitoring and assessment measures, such as tsunami early warning systems;
- MLA 4: Supporting science, technology and innovation policies for sustainable development and poverty eradication, and developing capacities in basic sciences, energy and engineering.

UNESCO STRATEGY FOR ACTION ON CLIMATE CHANGE AND THE INTERNATIONAL YEAR OF PLANET EARTH (IYPE)

The United Nations system is widely acknowledged as the central multilateral framework through which the international community can address global challenges, including a coherent approach to climate change. According to the Report by the Director-General on a DRAFT UNESCO Strategy for Action on Climate Change (Executive Board 179 EX/15, Item 15 of the provisional agenda), UNESCO's core contributions to address climate change rest on two principal pillars:

- (a) the sound and unbiased generation and use of data, information and research concerning climate change (the knowledge base);
- (b) the application of educational tools, specific sectoral measures and public awareness activities;

UNESCO's Strategy for Action on Climate Change consists of an integrated multidisciplinary programme capable of offering Member States capacity-building and technical advice to:

- design and implement evidence-based policies and projects at the local, national, subregional and regional levels.
- adopt measures to adapt to the impacts of climate change, contributing to mitigation of its causes and strengthening sustainable development.

In addition, 2008 has been designated by the United Nations General Assembly as the *International Year of Planet Earth (IYPE)*. Led by UNESCO and the International Union of Geological Sciences, the focus of the IYPE will be on the fundamental role of Earth sciences, within a resolutely interdisciplinary context, in maintaining a living and healthy Earth system, thus enabling prosperous and diverse human societies to envision a future based on the principles of sustainable development.

THE GREEN PAPER: CLIMATE CHANGE IMPACTS IN EUROPE, THE CASE FOR ACTION AND POLICY RESPONSES IN THE EU (BRUSSELS, 29.6.2007, COM(2007) 354 FINAL)

With climate change already happening, societies worldwide face the challenge of having to adapt to its impacts as a certain degree of climate change is inevitable.

The *Green Paper from the Commission to the Council* examines climate change impacts in Europe, the case for action and policy responses in the EU. It focuses on the role of the EU, but takes into account the prominent role of Member States, regional and local authorities in any efficient adaptation strategy. As the adaptation challenge is global by its very nature, the Green Paper also raises the external dimension and looks at adaptation measures in Europe that could also apply to other parts of the world, and the opportunity for the EU to provide international leadership in this area. The *Green Paper* also enhances the role of agriculture and forestry in developing adaptation strategies: "Under a

changing climate, the role of EU agriculture and forestry as providers of environmental and ecosystem services will further gain importance; Agricultural and forestry management have a major role to play; Promotion of climate resilient forest management, soil management measures related to maintenance of organic carbon and protection of permanent grasslands are mitigation measures that should also help adaptation to climate change risks.

CONFERENCE ON "CLIMATE CHANGE: CAN SOIL MAKE A DIFFERENCE? BRUSSELS, 12 JUNE 2008

The Conference on "Climate change: Can soil make a difference?" was organized and hosted by the Environment Directorate-General of the European Commission in Brussels on 12 June 2008 (http://ec.europa.eu/environment/soil/conf_en.ht). Focus of this Conference was the interrelationship between soil and climate change and the role of soil management in climate change mitigation and adaptation.

The opening address of Mr. Luc Gnacadja, UNCCD Executive Secretary (<http://www.unccd.int>), underlined that (i) the global importance of enhanced land and soil management is becoming increasingly clear, and inter-linkages between soil and climate change are significant and should be better reflected in policy-making processes, (ii) bringing agricultural land use into the realm of implementation mechanisms on climate change could re-define the concept and the content of international development cooperation, (iii) the political implications, as well as the increase of volume in financial and technological transactions targeting agriculture, as well as the improvement of the livelihood of the most vulnerable could be enormous.

Results of discussion and of the round table indicated the key role of soil management in any action finalized to climate change mitigation, and the need for linking climate change to soil protection for developing effective mitigation strategies and policy options. In particular, presentations and discussion addressed the need for linking Climate Change to the Soil Thematic Strategy (http://ec.europa.eu/environment/soil/three_en.htm) and its accompanying legislative proposal adopted by the European Commission in September 2006, as well as with the objectives presented in the *Green Paper on adaptation to climate change* adopted by the European Commission in June 2007.

Members of the European Parliament, the President of the Environment Council and other key players agreed that the role of soil as a repository of carbon must be enhanced. They discussed policy options for achieving this, and advocated the adoption of a *directive on the protection of soil*, along the lines of the Soil Framework Directive that was blocked by European Council last December.

THE THEMATIC STRATEGY FOR SOIL PROTECTION

The Thematic Strategy for Soil Protection consists in a communication from the Commission to the other European Institutions, a proposal for a framework Directive (a European law), and an Impact Assessment. The Communication (COM(2006) 231) sets the frame. It explains why further action is needed to ensure a high level of soil protection, sets the overall objective of the Strategy and explains what kind of measures must be taken. It establishes a ten-year work program for the European Commission. The Commission launched the consultation process in February 2002. It involved the EU Member States, Candidate Countries, European Institutions, Networks of Regional and Local Authorities and a broad community of European-wide Stakeholder Organisations.

An Advisory Forum and five Working Groups were set up, which produced the following reports (http://ec.europa.eu/environment/soil/index_en.htm):

- Volume 1 : Introduction and executive summary
- Volume 2 : Erosion
- Volume 3 : Organic matter
- Volume 4 : Contamination and land management
- Volume 5 : Monitoring
- Volume 6 : Research, sealing & cross-cutting issues

Soil is essentially a non-renewable resource and a very dynamic system which performs many functions and delivers services vital to human activities and ecosystems survival. Information available suggests that, over recent decades, there has been a significant increase of soil degradation processes, and there is evidence that they will further increase if no action is taken (Crescimanno et al., 2004; Castillo et al., 2004).

The soil question is expected to be addressed this autumn in a Commission White Paper on adaptation to climate change. The paper intends to stress the importance of making soil more resistant to climate change, and show how healthy, resilient soils can help society adapt to the impacts of climate change. Recent changes in the Common Agricultural Policy have also stepped up soil protection. Identification of areas at risk of erosion, organic matter decline, salinization, compaction and landslides, and establishment of national programmes of measures is necessary. To ensure a coherent and comparable approach, the identification of risk must be carried out on the basis of common elements.

CONCLUDING REMARKS

Strategies for soil protection need to be considered as an essential aspect of policies and management strategies for climate change mitigation. Management practices protecting soil from degradation caused by erosion, loss of organic carbon, salinization, contamination and desertification should be considered an integral part of comprehensive national development strategies for climate change mitigation. It is more urgent than ever to act in favour of appropriate policies and practices that will not only mitigate global warming, but will also diminish desertification risks, thereby sustaining agricultural production and facing the food crisis. Cooperation between different Organization and contribution from different actors is necessary to develop joint actions and to face the increasing problems and challenges.

This Working Group and this Workshop in Novi Sad are both initiatives aimed at achieving the mentioned objectives.



Fig. 2. Participants of the Working Group, Novi Sad, 10 July 2008

REFERENCES

- Castillo V., Arnoldussen A., Bautista S., Bazzoffi P., Crescimanno G., Imeson A., Barman R., Robert M., Rubio J. L.. 2004. *Taskgroup 6. Desertification*. Volume 2 Erosion. Edited by Lieve Van-Camp, Benilde Bujarrabal, Anna Rita Gentile, Robert J A Jones, Luca Montanarella, Claudia Olazabal, Senthil-Kumar Selvaradjou (2004). EUR 21319 EN/2. <http://ec.europa.eu/environment/soil/pdf/vol2.pdf>

- Crescimanno G., Lane M., Owens P.N., Rydell B., Jacobsen O.H., Düwel O., Holger Böken H., Berényi-Üveges J., Castillo V. and Imeson A..2004. *Taskgroup 5. Link with Organic matter and contamination working group and secondary soil threats. Reports of the technical working groups established under the thematic strategy for soil protection. Volume 2 Erosion.* Edited by Lieve Van-Camp, Benilde Bujarrabal, Anna Rita Gentile, Robert J A Jones, Luca Montanarella, Claudia Olazabal, Senthil-Kumar Selvaradjou (2004) EUR 21319 EN/2. <http://ec.europa.eu/environment/soil/pdf/vol2.pdf>
- Herrmann M. and Hutchinson C.F.. *The changing contexts of the desertification debate.* Journal of Arid Environment, Vol 63, Issue 3, November 2006, pp 538-555

Acknowledgements

I am grateful to Ms. Cristina Faccia for her valuable support in dealing with the organizational and contractual issues related to the Workshop, and for the efficient and continuous support she provided me with since the beginning of my appointment with UNESCO-BRESCE.

HARMONIZATION OF DEMANDS IN AGRICULTURE, FORESTRY AND ENVIRONMENT IN PLAIN PART OF SERBIA - PROBLEMS, SOLUTIONS AND CHALLENGES

Dr Saša Orlović, Mr Andrej Pilipović, Dr Vladica Galovic, Mr Leopold Poljaković Pajnik,
Mr Verica Vasic, Mr Predrag Pap

Institute of Lowland Forestry and Environment, Novi Sad, Republic of Serbia, Email: sasao@uns.ns.ac.yu

Summary: Modern agricultural production is characterised by use of certified seeds, intensive soil cultivation, intensive use of pesticides for control of diseases, insect pests and weeds, monocultures on large areas, and low diversity. In the *Vojvodina* region, agricultural production is the most dominant form of plant production. To ensure a sustainable agricultural production, as well as protection and enhancement of environmental quality, it is necessary to increase the extent of the present forest area up to 140,000 ha, i.e. from the present 6.37% to 14%. However, increasing the forest cover percentage is difficult because of lack of forest land. It is therefore necessary to apply alternative systems of land use to increase yield, and this objective can be achieved by combining the agricultural and forestry technologies, making the ecosystem more stable. Agro-forestry systems are alternative land uses with the main purpose of creating diverse, productive, profitable, healthy and ecologically more stable ecosystems. Agro-forestry is considered an alternative land use, which includes: alley cropping, windbreaks, riparian buffer strips, silvo-pastoral and forest farming. Agro-forestry systems will have special significance by the full implementation of the Kyoto Protocol, as carbon sequestration by perennial plants (trees) will be more adequately economically valorised. This paper presents a survey of different types of agroforestry plantations, as well potential solutions, related to selection of species.

Key Words: Agro-forestry/Afforestation

INTRODUCTION

Agro-forestry is an intensive system of land management which benefits from the biological interactions when trees or shrubs are grown with agricultural crops or livestock. It should be emphasised that agro-forestry is not a new technology, but a concept neglected in our region, which has been instead been practised in tropical and sub-tropical regions. Agroforestry systems help attaining sustainable agricultural land use systems in many ways. They provide protection for topsoil against erosion, protection of livestock and agricultural crops; increase productivity, reduce inputs of energy, increase water-use efficiency of plants and animals, improve water quality, enable diversification of revenues and enhance biodiversity and landscape amenity, and finally, the quality of life (Rietveld, 1996). The potential uses of agro-forestry are numerous, but they can be reduced to the following categories: alley cropping, windbreaks, riparian buffer strips, silvopastoral systems and forest farming.

Alley Cropping

Alley cropping is established on agricultural lands to increase the diversity of returns, reduce wind and water erosion, increase productivity in agriculture, enhance the utilisation of nutrients, improve the habitats with the aim of diversity conservation. They are actually tree plantations in single or multiple tree rows, at a wide spacing between the plants (minimum 6m), in which agricultural or horticultural plant species are planted. The most widely used trees are high-value hardwoods or soft hardwoods, as well as the species which produce fruits that can be used as food for people or livestock. Also, it is possible to establish intensive plantations of soft broadleaves (poplars) for the production of wood for pulp and paper. Frequently used species in the establishment of such plantations are walnut (good-quality and high-value wood and fruits), oaks (good-quality and high-value wood, acorn for livestock), ash (good-quality and high-value wood), wild cherry (high-value wood). Alley cropping may enhance economic stability, increase plant and animal diversity, sustainable management of agricultural systems and landscape diversity. One of the main questions when designing an alley cropping system is the issue of selecting tree species and spacing of tree rows. Due to the interaction between trees and agricultural species and the optimisation of economy, alley cropping should be created so as to ensure the highest rates of return of the investments in the establishment. If Black Walnut (*Juglans nigra*) is planted as a woody species, it is best to start with 270 plants/ha and to reduce the number of plants to 75/ha by later thinning (Garrett, *et al*, 1994). In alley

cropping, care must be taken about the characteristics of tree species, as well as the landowner objectives and priorities. Special attention must be focused in the selection of plant species that are compatible with the site. Selected tree species should have the following characteristics:

- To produce high-value products, such as wood, fruits, chemical compounds, etc., with a viable market;
- To ensure fast yield;
- To adapt to different site and soil conditions;
- To provide shade for the growth of some agricultural species;
- To have deep root systems, to avoid the competition of agricultural species;
- To have the foliage which have a minimal potential of soil acidification;
- Do not produce substances which inhibit the growth of agricultural species;
- To have the same growth season as the agricultural species grown between the rows,
- To enhance diversity.

In the selection of tree species, it is necessary to take into account the growth characteristics of the species for alley cropping, the number of rows - single or multiple tree rows, the application of single or multiple species, spacing, as well as the species demands for light. It is especially necessary to know the growth characteristics of tree species during the juvenile stage, because of the possible competition with the crops.

The spacing between rows and between plants is very important in the design of alley cropping. It depends on the special purpose of the plantations, i.e. if alley cropping is intended for the production of wood for fibres, spacing is narrower. If the plantations are intended for erosion control spacing is also narrower, but instead for production of fruits spacing is wider. If the species selected for alley cropping do not tolerate shade, the planting spaces should be wider. Also, the spacing depends on the demands for fertilisation, maintenance, or weed suppression during plant growth. Very often, an intensive multi-crop system (cultivation of several plant species) ensures a much higher profit than tree growing only for timber (Kurtz, *et al.*, 1984)

Windbreaks

Windbreaks are line plantations of trees and shrubs which are established to reduce wind velocity in a given area. Windbreak establishment and management are the main components of management and growing of agricultural crops or livestock. Special significance of windbreaks is environmental protection, i.e. reduction of wind erosion. In addition, the quality of water and air is enhanced, thanks to the filtering and remediation. The lower wind speed enables the higher efficiency of water utilisation, through the reduced evapo-transpiration. Windbreaks also increase the economic benefits because they reduce the energy costs for heating; they increase the yield, enhance the livestock health and vitality and enable the production of fruits or wood. The research shows a significant increase of yield in agricultural crops (10 - 20%) if plants are protected by windbreaks. The percentage varies depending on the soil conditions and the year (Baldwin, 1988; Kort, 1988). Windbreak establishment leads to the reduction of height of the plants within the shelterbelt, but this loss is compensated by the increased yields on the remaining area, thanks to the reduction of wind speed (Baldwin, 1988). Efficiency of pesticide application, as well as pollination success, is also significantly higher (Wight & Stuhr, 2002).

Windbreaks have an important role in the protection of livestock from cold and severe winds during autumn, winter and spring, also providing protection from insolation in summer (Quam *et al.*, 1994). Due to reduction of wind speed, livestock is protected from colds, it is healthier, efficacy of food is higher and reproduction cycle is enhanced. Windbreaks also provide the increase of yield in bee keeping, because they provide favourable plants for bees, as well as the shelter to bees from wind (Gordon & Newman, 2006).

Windbreaks have a favourable effect on the increase of biodiversity due to cultivation of multiple species in windbreaks, which increases the potential of nourishment for animals, birds and insects; at the same time windbreaks provide corridors for movement and protection. Also, thanks to greater diversity, there are better opportunities for hunting, which is a significant activity for the enhancement of rural revenues. Landscape beauty is enhanced by colours, shapes and noises (Johnson & Brandle, 1991).

Windbreaks decrease energy consumption for heating and cooling. During winter months the decrease of velocity of cold winds, may determine saving ranging between 10 and 40%. If windbreaks are established along the roads, they reduce noise and protect roads from blowing snow (Wight and Stuhr, 2002).

In the Autonomous Province of Vojvodina, there is a significant demand for the establishment of about 90,000 ha of windbreaks (Orlovic, 2005). They are necessary to provide the ecosystem stability and to maintain the level of agricultural production.

Riparian Buffer Strips

The lack of permanent vegetation, i.e. trees and shrubs, grass and annual plants leads to the increase of water runoff containing different sediments and dissolved contaminants which are delivered to surface waters. The increased runoff causes stream-bank erosion which leads to degradation of aquatic habitats and increased deposition of sediments in rivers and lakes. In most cases water transports a number of contaminants, such as: fertilizers, pesticides, nutrients and bacteria from livestock operations, sediments from croplands and urban areas and eroding stream-banks, oils (Gordon & Kaushik, 1987). When these pollutants reach rivers or seas, they create hypoxic zones in which fish cannot survive. Hypoxic zones are created also when excess of nitrates reaches the rivers, especially in the spring. To prevent this negative trend, riparian buffer strips, or tree and shrub plantations, need to be established to decrease the harmful impacts and to enhance the conditions for fish and wildlife habitat. There are numerous data on the adverse effects of removal of forest plantations along the stream-banks, but there are few data on the cumulative rehabilitation effects of artificially established forests on degraded waterways (Borman & Likens, 1979). Data from a locality in Ontario (Canada, 1987) show that three years after tree planting along the Grand River, the number of plants was significantly higher compared to some non-rehabilitated areas. The same study also showed that after 5 years the planted trees provided a significant shade, lower air temperature, a 20% reduction in nitrates concentrations in water, and the production of significant biomass quantities (4-5 oven-dry Mg ha⁻¹ year⁻¹) [5]. Recent research in this area showed a significant increase in the number of fish and the populations of mammals and birds, from which it can be concluded that riparian corridors are significant for the activities on restoration and rehabilitation of biological diversity (Spackman & Hughes, 1995), as well as that they have a significant buffering capacity to remedy the contamination. This practically means that the establishment of riparian buffer strips is one of the methods for the enhancement of diversity of agricultural lands.

Intensive production in animal husbandry in Vojvodina leads to production of high quantities of organic waste (slurry, manure), a great part of which is delivered to watercourses. By establishing and intensifying the existing riparian buffer strips, the deposition of nitrates, oil derivatives and heavy metals in the existing watercourses will be significantly reduced. Poplar plantations established for different purposes can be useful to achieve this objective. It is especially important to take into account the selection of poplar clones, because different poplar clones have specific reactions to the pollutants.

Silvopastoral systems

The traditional interaction between trees and livestock occurs at places where trees are used for shade (shade trees in pasture), where forests are used for grazing and where there are trees and shrubs on pastures. A silvo-pastoral system consists of livestock, forage - pasture and trees. The trees provide protection against cold winds as well as the sun and dry winds. In addition, farmers can provide significant returns by harvesting the fruits and wood. The land use for pasturage and tree growing can provide significant quantities of wood for mechanical and chemical wood processing. Numerous fruits, such as black walnut, hazelnut, almond and berries can be produced as secondary products. On such areas, the enhancement of biodiversity is significant. In the Autonomous Province of Vojvodina, there are large areas under pastures. Part of these lands is undergoing a significant process of salinization, and is now used only as pastures. Planting some tree species on such lands (common oak, blackthorn, wild pear, honey locust, etc.) would provide shade during summer days, and grass vegetation serving as pasturage, decreasing dryness due to insolation. In addition, this would create a significant pasture for honey bees, because the greatest numbers of tree and shrub species that thrive on such soils are also melliferous. Production of honey and bee products would be a significant contribution to the economic stability of farmers and to rural development.

CONCLUSIONS

Agro-forestry is a method of land management that enables integration of production and environmental management, which results in a healthier and sustainable agricultural production important for future generations. Agro-forestry systems, which are almost absent in Serbia, can provide significant economic effects, such as: diversifying income, reduction of inputs of energy, increase in agricultural production; positive effects on the environment: quality of air, water, soil and plants, as well as enhancing of biodiversity and could be appropriate ways for harmonisation of demands from agriculture, forestry and environment.

REFERENCES

- Baldwin, C.S. (1988). The Influence of Field Windbreaks on vegetable and Specialty Crops. *Agriculture, Ecosystems and Environment* 22/23: 191-203
- Borman, F.H., Likens, G.E. (1979). *Pattern and Process in a Forested Ecosystem*. Springer-Verlag, New York, USA
- Garrett, H.E., Buck, L.E., Gold, M.H., Hardesty, L.H., Kurtz, W.B., Lassoie, J.P., Pearson, H.A., Slusher, J.P. (1994). *Agroforestry: An Integrated Land-Use Management System for Production and Farmland Conservation*. Resource Conservation Act (RCA) Appraisal of U.S. Agroforestry, 58 p. USDA Natural Resources Conservation Service.
- Gordon, A.M., Kaushik, N.K. (1987). Riparian Forest Plantations in Agriculture: The beginnings. *Highlights of Agricultural Research in Ontario* 10: 6-8
- Gordon, A., Newman, S. (2006). *Temperate Agroforestry Systems*. Cab International. p.269
- Johnson, R., Brandle, B.J. (1991). *Windbreaks and Wildlife*. University of Nebraska. p.1-7
- Kort, J. (1988). Benefits of Windbreaks to field and Forage Crops. *Agriculture, Ecosystems and Environment* 22/23: 165-190
- Kurtz, W.B., Garrett, G.E., and Kincaid, W.H. (1984). Investment alternatives for black walnut plantation management. *J. For.*, 82: 604-608
- Orlović, S. (2005). Stanje šuma i potencijali u AP Vojvodini. p.139**
- Spackman, S.C., Hughes, J.W. (1995). Assessment of Minimum Stream Corridor width for Biological Conservation: species richness and distribution along mid-order streams in Vermont, USA. *Biological Conservation* 71: 325-332
- Quam, V., Gardner, J., Brandle, L. (1994). *Windbreaks in Sustainable Agricultural Systems*. University of Nebraska. p.1-4
- Wight, B., Stuhr, K. (2002). *Windbreaks: An Agroforestry Practice* 1:1-4

LAND DEGRADATION IN THE FORMER YUGOSLAV REPUBLIC OF MACEDONIA

Ivan Blinkov¹, Dusko Mukaetov², Ordan Cukaliev¹

¹University "St. Cyril and Methodius", Faculty of Forestry – Skopje,
bul."Alexandar Makedonski " bb. 1000 Skopje, Former Yugoslav Republic of Macedonia,
fax: +389 2 3164560; phone: +389 2 3135 033 /ext.152; E-mail: blinkov@sf.ukim.edu.mk

¹University "St. Cyril and Methodius", Institute of Agriculture – Skopje,
bul."Alexandar Makedonski " bb. 1000 Skopje, Former Yugoslav Republic of Macedonia,
fax: +389 2 3114 283 ; phone: +389 2 3230 910 /ext.200 ; E-mail: d.mukaetov@zeminst.edu.mk

¹University "St. Cyril and Methodius", Faculty of Agricultural Sciences and Food – Skopje,
bul."Alexandar Makedonski " bb. 1000 Skopje, Former Yugoslav Republic of Macedonia,
Fax: +389 2 3115 277; phone: +389 2 3115 277 /ext.101;
E-mail: Ordan.Cukaliev@zf.ukim.edu.mk

Abstract: This paper is a review of land degradation processes in the Former Yugoslav Republic of Macedonia (in the following **also referred to** FYRoM). The first part provides basic information about FYRoM, the second one provides a detailed description of all factors related to land degradation.

INTRODUCTION

The Former Yugoslav Republic of Macedonia is located in the central part of the Balkan Peninsula. It is a landlocked country having an area of 25,713 km², with approximately 80% of the entire territory located in mountainous regions. About 2% of the land area is covered by water, comprising 35 large and small rivers, 3 natural lakes (Ohrid Lake, Prespa Lake, Dojran Lake), and over 100 artificial lakes. The population of the country is represented by about 2 million people, with about 60% living in urban areas, and an overall population density of 81 inhabitants per km².

Industry is the dominant sector, accounting for 35% of Gross Social Product (GSP) and for 39.9 % of employment. Agriculture, combined with forestry and fishing and the service sector, accounts for 22% and 30% of the GSP, respectively. Nearly half of the total area of the country is used for agriculture, equally split between cultivated areas and pastures. Forest cover plays an important ecological function for watershed protection and soil conservation. About 37% of total territory of the country can be classified as forest land; this percentage can be considered rather high in comparison to other countries in Europe.

Natural conditions

Although the Former Yugoslav Republic of Macedonia has a rather small territory (25,713 km²), it shows a great diversity of natural conditions, with almost all relief forms, geological formations, climatic influences, plant associations and soils which appear in Europe. Differences in altitude range from 40 to 2,764 m above the sea level. In the Former Yugoslav Republic of Macedonia there are a number of geological formations of a very heterogeneous petrography-mineralogical composition. Mountains are composed of compact rocks, basins are composed of sediments, undulating-hilly terrains in basins are composed of sea and lake sediments (Palaeogene, neogenic, dilluvial deposits etc.). A considerable heterogeneity appears in the soil cover too (over 40 different soil types). The territory of the Former Yugoslav Republic of Macedonia belongs to three basins: Black Sea Basin (44 km² or 0.17 %); Adriatic Sea Basin (3,359 km² or 13.07 %) Aegean Sea Basin (22,310 km² or 86.76 %). About 80% of the relief is in the high hills-mountain zone. Some regions in the country have large bands of ground (the western part of the country) and the relief is dissected with a lot of depressions.

Climate conditions

The country is under the influence of two climate zones (Mediterranean and temperate-eastern continental) and one local (mountain) climate. As a result of heterogeneous natural conditions, the territory of FYRoM can be classified into eight different climate-soil-vegetation zones (sub Mediterranean, continental-

sub Mediterranean, warm continental, cold continental, piedmont-continental-mountain, mountain-continental, sub alpine-mountain, alpine-mountain).

On the basis of data collected during the period 1960-2000, at gauge stations located in four arid and in eight semiarid regions of the **country**, average values of precipitations range from 450 up to 650 mm, potential evapo-transpiration from 708 to 790 mm, and aridity index ranges between 0.60 and 0.80, with 6-8 arid and semiarid months per year.

Land Use

About 25% (634,000 ha) of the total land area is represented by pasture land, 21% (550,000 ha) by arable land, 2% (55,300 ha) by meadows, 2% (57,000 ha) by vineyards and orchards, 8% (205,000 ha) by barren land, 37,5% (965650 ha) by forest land, 2% by lakes, and 2.5% by urban or industrial land.

About 50% of the land area, representing 1.3 million ha, is arable land or pasture. Fertile land is scarce, with 82% of arable land in fertility classes IV to VII. Because of recent declines in rural population and economic activity, fallow and uncultivated land is increasing, extending to an area of about 160,000 ha in 1993, which represents 30% of arable land. Pasture land represents about 634,000 ha, but yields are below potential rates, averaging only about 270 kg/ha (potential yields could be as high as 800 kg/ha).

Forest reserves cover about 1 million ha, or 37,5 % of the land area of the country, and about 50% of forests comprises pure and mixed oak stands (480,000 ha), 29% (285,000 ha) beech stands, 8% (80,000 ha) Black Pine and Scotch Pine), 15% other stands. A considerable percentage of forests in the **country** are degraded. This is characteristic for oak stands. Degraded forests and shrubs cover 262,000 ha (27%) of the forest land. A substantial proportion of the forest is located on steeply sloping land, where forest cover is necessary for soil. Deforestation was severe before the Second World War. Since then there has been a program aimed at restoring and reserving forests. Forests found after the WWII were about 550,000 ha, but now it is about 960,000 ha. About 190,000 ha of shrubs have been transformed into coppice forest.

Land Degradation in the Former Yugoslav Republic of Macedonia

In general, land degradation is defined as the decline of the natural land resources, commonly caused by improper use of the land. It can also be defined as the reduction or loss of biological or economic productivity and complexity of land, resulting from human activities. Land degradation encompasses: soil degradation, de-balance of the hydrological regime, deterioration or loss of vegetation and landscape functions. Land degradation directly affects plant growth, which further reduces biomass production and protective soil cover. As a consequence, erosion processes increase, soil characteristics worsen, hydrological regime become more unbalanced, finally leading to loss of plants and formation of semi desert or desert. This is a complex process which finally leads to desert formation, especially in arid, semiarid and dry continental climatic conditions.

Soil degradation has physical, chemical and biological dimensions. According to ESB (European Soil Bureau), nine different types of soil degradation can be recognized, i.e. acidification, alkalisation and salinisation, loss of organic matter and bioactivity, loss of nutrients, change of physical characteristics, physical destruction, soil sealing, pollution and erosion.

Soil degradation in FYRoM

Due to climatic conditions and other factors related to soil acidification, this type of soil degradation is insignificant in FYRoM.

There are instead 11,000 ha of saline soils located in the driest region in the country (Ovce Pole). This represents only an approximate extension, because due to absence of monitoring or of any research, the status and extension of salinization in FYRoM cannot be accurately assessed. However, it can be stated that wherever irrigation of agricultural crops is applied without any previous investigation on soil conditions and plant demands, the process of salinization is likely to occur. Under **conditions of so called "wild" irrigation** and without any monitoring of soil indicators, it is impossible to estimate the extent of salinization. There are almost 120,000 ha of arable land in the country that can be actually irrigated. Every year, depending on water availability, rainfall and cultivated crops, about 30,000-80,000 hectares are usually irrigated. Considering the above mentioned low degree of know-how in application of irrigation techniques, it can be stated that the whole irrigated area is prone to salinization. Improper irrigation has a significant influence on

soil salinization, especially (i) if water with a high salt content is used, leads to accumulation of salts in topsoil and (ii) if excess of water is applied, which increases the level of ground water, bringing up dissolved salts and enhancing soil salinization.

Organic matter depletion is a process currently occurring in areas with intensive agriculture. Unfortunately there is no monitoring system regarding the OM status in climatologically different regions under different crops and agricultural practices. Regular testing of soil properties and fertilization based on recommendations of the specialists is not a common practice. The problem expands due to a prolonged use of the same formulations for mineral fertilizers e.g. NPK 15:15:15, and scarce use of manure. There are some scattered studies and elaborations which refer to OM content in the soil, but they are not the result of systematic investigations, which should be performed in different sites with different levels of degradation.

It is clear that there is a loss of organic matter, nutrients and bioactivity, as a result of current agricultural practices in the country. There is a lack of soil conservation activities. Moldboard plough is predominant in the country although there was evidence that no tillage or reduced cultivation can be considered better techniques. There is a need for upgrading the public awareness through technology transfer ending with education of all involved stakeholders in using new approach and techniques.

The cultivation systems (tillage and management systems), have a considerable influence on the physical properties of the soil.

Physical degradation of the soil may be defined as the loss of the soil structural quality. This structural degradation may be observed both on the surface where thin crusts may be seen, and also below the surface in or below the ploughed horizon where compacted layers may be formed. With this type of degradation, the infiltration rates of the water into the soil are reduced, whilst the rates of runoff and erosion increase. Degradation of soil physical quality should be evaluated by monitoring changes in some relevant physical characteristics such as density, porosity, pore-size distribution, structural stability and infiltration rate. The main causes of degradation of the soil physical properties are: (a) deterioration of vegetation, (b) depletion and loss of organic matter, (c) incorrect and excessive tillage.

As a result of modernization, urban growth, human needs and migration processes, soil sealing is becoming a serious problem. A considerable amount of high-class agriculture land has been sealed with different infrastructural objects with widening of the city on higher-class land. Typical examples are Skopje, Bitola, Kumanovo, and Tetovo. Until 1963, there were 250,000 citizens in Skopje. After the earthquake (1963) as a result of the migration processes, the number of citizens increased to 320,000. **Today** in Skopje and in the surrounding neighbourhood, about 600,000 citizens live. After the earthquake, a lot of new areas were built on high-class agriculture land. There is industrial infrastructure located into the agriculture zone. There are new roads (highways, motorways) constructed into the agriculture zone. Besides soil sealing, all these structures are a source of soil pollution too.

Soil Pollution

There is a considerable problem of soil pollution with nitrates, phosphates, sulphates, pesticides, organic pollutants, heavy metals, oil. There is no monitoring system. There are some erratic measures of soil pollution around some industrial complexes but these results are relevant only for those localities.

Pollution from Agriculture

Fertilizer use is declining in the last 18 years, especially during the period of 1990-93, mostly due to the lack of finances, but fertilizers' use remains quite high. Fertilizers' consumption in the agricultural cooperatives is higher than in the private sector. Consumption of mineral fertilizers declined from 43,000 tons to 24,000 tons from 1982-92, but consumption of nitrates increased from 35,000 tons to 48,000 tons. In order to maximize the yield per unit area, farmers are increasing the inputs of application of very high fertilizer rates. In such situation farmers are not interested in crop rotation with other low profitable crops, and therefore the condition of land degradation is getting worse. Up to now, very few systematic studies for the impact of fertilizer use on land degradation have been performed, and no reliable data are available for an accurate estimation of the situation.

Organic manure production is about 3 million tons, out of which about 40% is sheep manure, 40% from large ruminants and pigs, and 20% from poultry. Organic manure satisfies about 30% of total fertilizer demand. The availability of manure is a big problem, since the animal production is located in limited areas.

Moving the manure from one to the other area is very expensive and not profitable for farmers. This means that even if manure has a very positive effect on soil in agricultural production, there is a risk of pollution in areas where it is overproduced, and shortage in other areas. Serious investigations should be carried out to assess the situation in the country.

Pesticide consumption has declined dramatically over the past decades, from 2,706 tons in 1983 to 659 tons in 1993. Herbicide consumption has similarly declined. Analysis suggests that there are few problems in the Former Yugoslav Republic of Macedonia regarding retention of pesticide chemical residuals in vegetable products, partly because pesticide use is much lower than in Western Europe, and partly because standards are respected.

Pollution from Other Sources

There are about 25 known landfills in the country. With the exception of Drisla landfill in Skopje, all other landfills are not appropriately designed. Therefore, leaching of toxic elements in soil can easily occur. In addition, these landfills are usually constructed on alluvial or other sediment soil, thus creating a potential hazard for groundwater contamination. There is no systematic monitoring, and the effect of landfills on groundwater and soil is not known. Typical municipal waste contains 25% ash and construction wastes, 24% paper, 20% food wastes, 11% plastic, 5% glass and porcelain, 4% textiles and leather, 3% metals, and 8% other kinds of wastes.

Large quantities of industrial and hazardous wastes are generated in the mining, metallurgical, fertilizer, and chemical industries as well as from power plants. Due to their toxic nature, management of such wastes becomes extremely important in order to diminish its negative impact on human health and environment. Slag disposal sites for lead and zinc smelter in Veles and 'Jugochrom', near Tetovo creates serious potential for soil and groundwater contamination. Proper waste management is also required for the ferro-nickel plant of Fenimak which generates about 430,000 tons of slag per year and at the thermal power plant in Bitola which has an ash pond that is more than 1,000 hectares. Smaller industries sometimes dispose their wastes off-site which affect the environment with degradation of nearby soil and water flows, e.g. cases with contamination of Zletovska Rive, Vardar River and Bregalnica River.

Soil Erosion

This is the dominant type of soil degradation in the Former Yugoslav Republic of Republic of Macedonia. A number of natural conditions in the country (climate conditions; topography characteristic; vegetation cover; geology) contribute to determine severe erosion processes. Also, poor arable farming, grazing management, and deforestation in the past contributed to erosion, a problem which is widespread all over the country. Deforestation was extreme before WWII. Inadequate ploughing and irrigation led to different processes of sheet and rill erosion. There are considerable losses of topsoil, humus and nutrients from the agriculture land located on the steep slopes. Although plugging in slopes higher than 15% is not allowed, many people in the hilly-mountain region practice that for surviving. Torrent erosion is a problem too.

Processes of water erosion are dominant because of the terrain configuration in the west part of **the country's** configuration, which is roughness and steep. In the central part of FYRoM, processes of sheet erosion are dominant. There is wind erosion in this part, but its intensity is not so high. Mixed processes are widespread in the eastern part of FYRoM. Gully erosion is spread all over the country. There are shallow and deep landslides also. Landfalls are also evident, more in the western part of the country. Sedimentation into the reservoirs is a very serious problem, and water management enterprises therefore invest in erosion control, by monitoring the sedimentation regime and intensity. Erosion maps were prepared with great support of public water enterprise. There is an Erosion Map prepared at a scale 1:50000 in a database version. A digital version was finished in the year 2002. The Erosion Map was performed by applying the empirical methodology of Gavrilovic (which is similar to methodology by Poljakov). Due to Gavrilovic, there are 5 category and 12 subcategories of erosion intensity (extreme, high, medium, low, very low).

Erosion intensity was mapped directly on terrain. The Erosion distribution is as follow:

The Extreme erosion – 69,800 ha, High erosion (II) – 183,200 ha, Medium erosion (III) – 689,300 ha, Low erosion (IV) – 793,600 ha, Very low erosion (V) – 746,300 ha.

According to the Erosion Map, 96.5% of the total area is under processes of erosion. An amount of 9,423 km² or 36.65% of the total state territory is encompassed by stronger categories (I – III). The

total annual production of erosive materials on the whole territory is about $17 \cdot 10^6$ [m³ /year] or 685 [m³ / km² year], which of $7.5 \cdot 10^6$ [m³ /year] or 303 [m³ / km². year] are carried by. Significant part of these deposits, about $3 \cdot 10^6$ [m³ /year] is not carried through the downstream sections of the rivers to the exit the state territory, but deposited in natural lakes and artificial reservoirs. Annual soil loss represents an annual average loss of arable soil layer of 20mm deep on an area of 8,500 ha. The economic cost of erosion impacts is thus considerable.

There are 106 different irrigation schemes in the country with a capacity to serve 124,000 hectares (ha). However, due to inefficiencies in the systems no more than 80,000 ha are irrigated. Erosion due to inadequate irrigation practices, such as furrow irrigation on sloping land, is less serious. About 40,000 ha of irrigated land is subject to erosion, with an annual average soil loss of about 300,000 m³. However, this soil is generally very fertile. About 60% of the irrigation is performed by sprinkler systems, while the remaining by furrows. Most of the irrigation systems (which accounts for more than 50% of the irrigated land), are more than 15 years old and many of them are seriously damaged. In the 1992, due to running out from the damaged main channel, a big landslide had happened in Timjanik (central part of the Former Yugoslav Republic of Macedonia) and several hectares of vineyards were destroyed.

As part of the erosion control program an "Afforestation Fund" was established in 1970. Through these measures a total of 164 360 ha were afforested which was 260% more than the planned growth. Since 1990 afforestation has declined by 66%, mainly because of budget constraints. In such an environment of limited available resources, a program to prioritize areas for afforestation would be useful. There are conflicts in certain areas between afforestation of barren lands and preservation of pastures, even though it is of poor quality. Till 1990, erosion control measures and activities were on **"higher level" and institutional support was higher. There was** a section for erosion control in all regional water management enterprise. There was part of the budget aimed at controlling erosion. Now, the situation is reversed. Unfortunately, erosion is one the biggest environmental and economic problems in Macedonia, but no special Act or regulation for erosion control exists.

Hydrological Regime

The last decade of the 20th century has been characterized by dry and extremely dry periods, with a decrease in total precipitation, and increase in frequency of high intensity rainfall.

Maximum daily (24 hours) values of rainfalls registered in the country have been 188 mm (g.s. Popova Sapka in 1979, and 175 mm (g.s. Demir Kapija) in 1995. High intensity rainfall in 1979 caused appearance of extreme water discharge of river Vardar ($Q_{max} = 980 \text{ m}^3/\text{s}$) and debris flow and mud flow of smaller rivers and torrents in the west part of FYRoM. As a result of high intensity rainfalls in 1995, estimated water discharge of small river Negotinska was $220 \text{ m}^3/\text{s}$. The 1% probability of occurrence of discharge for the same river is estimated to be $69 \text{ m}^3/\text{s}$. It is very important to mention that the specific surface runoff was $12 \text{ m}^3/\text{s} \cdot \text{km}^2$ which is one of the highest in Europe. Torrential flows (flash floods) are very frequent. **There isn't any city in** the country without problems - with torrents and consequences of them: sedimentation of lot of material in the urban area, destroyed streets, bridges, houses, other infrastructure facilities and they cover agricultural land with sterile sediments (stones, gravel, etc.). Exactly 1539 torrents are registered over the whole country territory. Their total catchments area is around 18 000 km² (70% of the state territory). Small torrents (with catchment area less than 5 km²) are 62% of the total number. Although their catchment area is small, there are torrents which pick up the flow achieve more than $30 \text{ m}^3 / \text{sec}$, that results in a considerable amount of sediment on the flooded areas.

Deterioration or Loss of Vegetation

There are two groups of reasons for deterioration and loss of vegetation. First one is natural reasons, and second one is human induced reasons. Natural reasons should be investigated more in frame of biodiversity.

In the last two decades a trend of forest deterioration has been observed. According to experts, the main problem was the drought period, which caused decreasing of vegetation condition, decreasing of resistance to pests and to diseases. These factors determined increasing problems with pests and diseases in the last period.

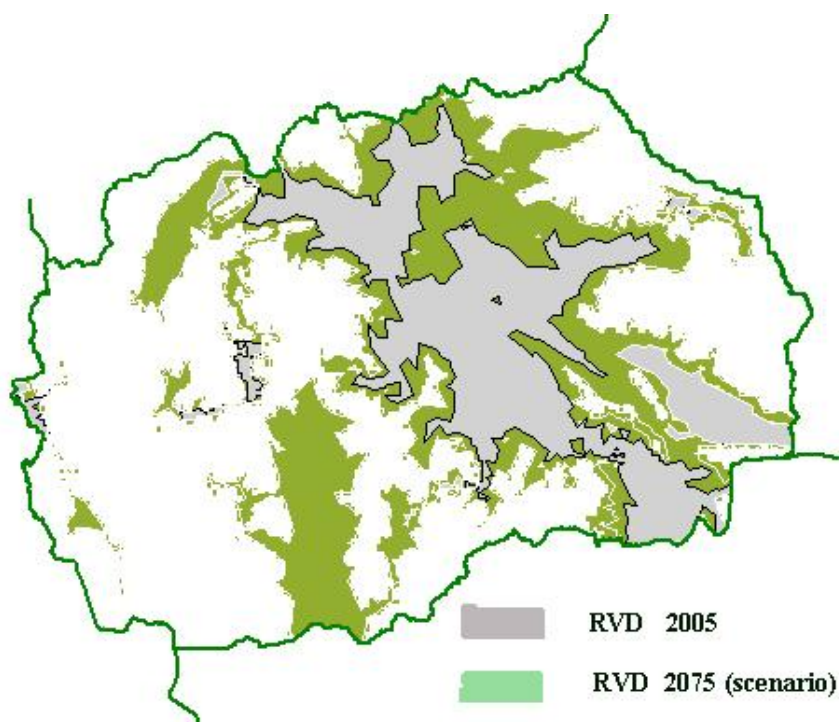
As a result of drought conditions and human mismanagement, fires destroyed about 6,500 ha of forest and of forest land. This is a very important problem for the country. Very often Shepard

uncontrolled burn juniper bushes, then fires extend to the forest and destroy great part of them. About 48,000 ha forest and grass were fired and destroyed in the year 2000.

Desertification in Former Yugoslav Republic of Macedonia

According to the Convention for combating desertification, regions vulnerable to desertification are those where the annual correlation between average annual precipitation amount and evapotranspiration is 0,5-0,65. There are four regions in the country: Sveti Nikole, Stip, Kavadarci and Veles which are currently under these conditions. Climatic conditions in Skopje and Kocani are close to the limit according to the mentioned indicators. However, the problem is again the lack of accurate data in the country on potential evapotranspiration, including the spatial distribution which is essential for elaboration of thematic map with delineation of vulnerable areas. Data for potential evapotranspiration calculated according Thornthwhite are available for all major meteorological stations in the Former Yugoslav Republic of Macedonia (31 stations), but this not sufficient.

There is no research or investigation aimed at identifying or delineating areas with high risk of desertification and drought. On the basis of the existing high resolution maps of temperature and rainfall a thematic map of Lang index has been prepared. As it can be seen, the calculated scenario for the next 70 years shows that the areas with Lang index bellow 20 will be extended dramatically especially in the central and south region of the country.



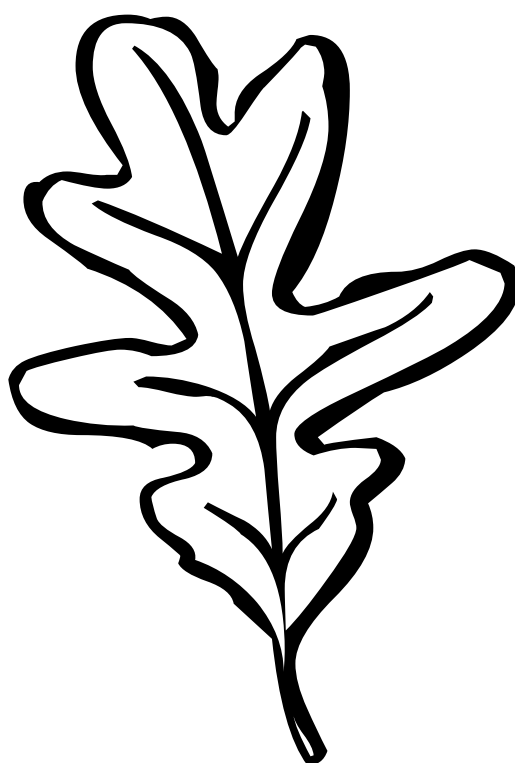
Map 1: Regional vulnerable to desertification processes in FYRoM
(Based on measured data and the Scenario for Climate Changes IS92 for the Year 2075
P -25%; Ts +2.5oC)

REFERENCES:

- Filipovski, G., Risteski, P., Rizovski, R., : 1996 *Characteristics of soil-climate-vegetation zones in the Republic of Macedonia*, MANU, Skopje, Republic of Macedonia
- Blinkov I., 2001 *"Soil erosion and control"* - textbook for students of Environmental engineering, Skopje, Republic of Macedonia
- Gorgevic, M., Jelic, D., Trendafilov, A., 1993. *Erosion Map of the Republic of Macedonia*
-

MOEPP&UNDP (Stavric, Cukaliev, Mukaetov, Blinkov, Donevska, Ristevski) 2004, *Self Assessment of Country Capacity Needs for Global Environment Management, Capacity Self Assessment within the Thematic Area of Land Degradation and Desertification*,

MOEPP&UNDP (Stavric, Cukaliev, Mukaetov, Blinkov) 2005, *National strategy with Action Plan to Combat Land Degradation and desertification- draft material*



AGROMETEOROLOGICAL AND BIOMETEOROLOGICAL CONDITIONS IN BOSNIA AND HERZEGOVINA IN THE LAST TEN YEARS

Željko Majstorović,
Sabina Hodžić, Nedžad Voljević, Dzenan Zulum

Federal Hydrometeorological Institute of Bosnia and Herzegovina, Sarajevo.
Emails: zeljkom@fhmzbih.gov.ba; sabinah@fhmzbih.gov.ba; nedzadv@fhmzbih.gov.ba;
dzenanz@fhmzbih.gov.ba

Summary : In the the last ten years significant weather variabilities followed by very warm and very cold short periods were observed in the territory of Bosnia and Herzegovina. They affected the regime of temperatures and precipitations, as well as others agrometeorological conditions.

A great impact was evident in the begining of period by average daily temperatures higher or equal to 5 °C, which are directly connected with duration of vegetative periods. Concomitant changes in number and duration of drought period were also observed. Values of De Martonne Index show trends indicating an increase in drought.

Water balance also shows a significant variability according to the changes in the regime of precipitations. Longer drought periods, extreme precipitations and a lower number of days with snow cover appear to be more frequent. All these factors have an evident influence on vegetation.

During 2007, drought period extended from April to August, accompanied by the wave of high temperatures during summer and by high-intensity short-term precipitations in May and June, which determined a low infiltration.

Keywords: drought period, heat and cold waves, vegetation period, precipitation, effective temperatures

INTRODUCTION

The last decade (1997-2006) was the warmest in the last 50 years in the territory of B&H and 2007 is the fifth warmest year since collection of meteorological observations started in Bosnia and Herzegovina. 2007 was a special year not only because of the high temperatures, but because of the occurrence of very warm and very cold short periods. To analyze this phenomena, we used data collected and compared at the following Stations:

Station	φ	λ	Hs
Mostar	43 21	17 48	99
Sanski Most	44 46	16 42	158
Sarajevo	43 52	18 26	630
Gradacac	44 53	18 26	140
Bjelašnica	43 43	18 16	2067

We decided to research agrometeorological conditions in Bosnia and Herzegovina within last ten years with similar ones collected from 1961 to 1990.

Figure 1a shows anomalies in the average decade temperature at the Sarajevo station.

Figure 1a. Anomalies in decades temperatures

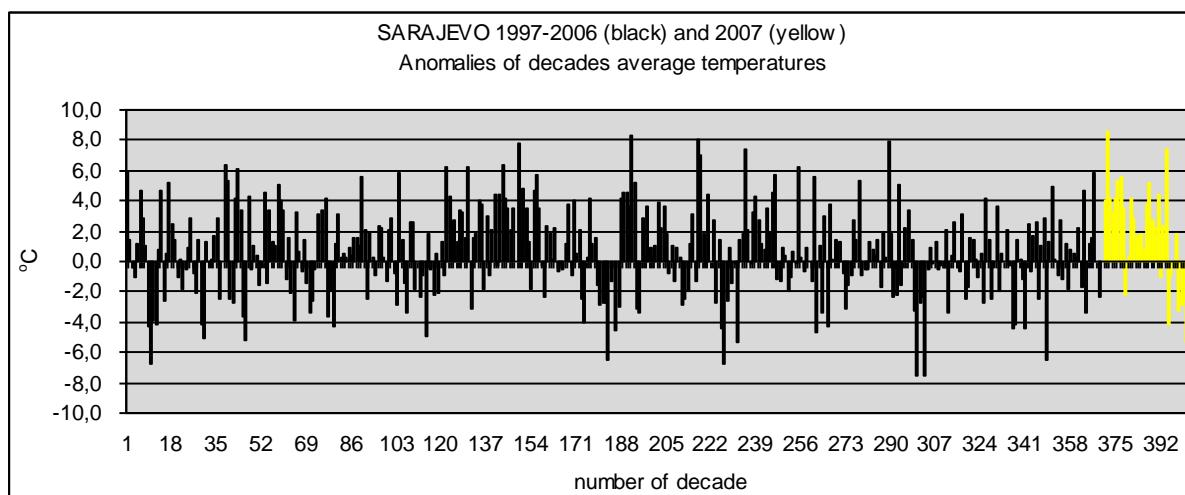
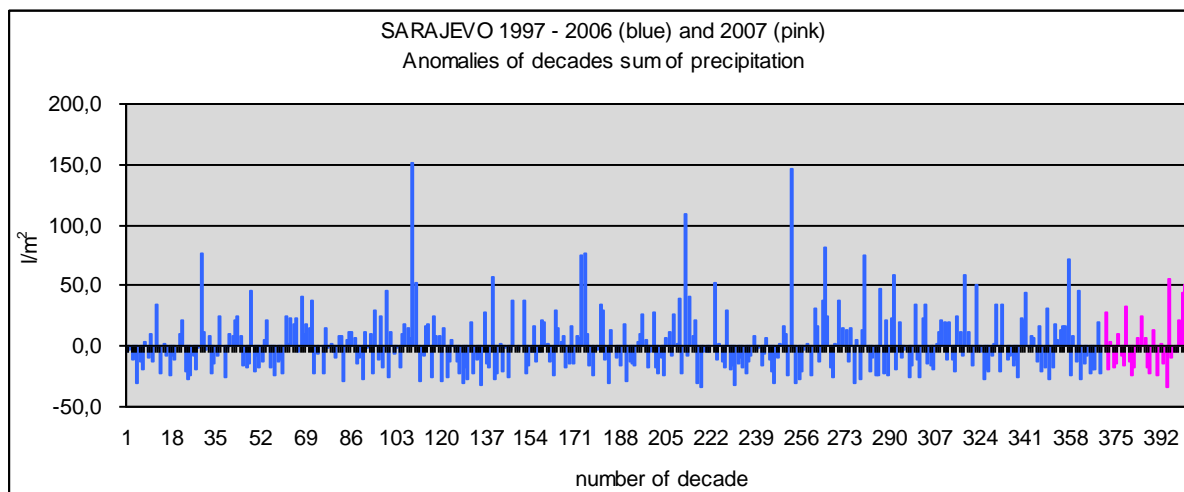


Figure 1a shows a great variability in the **decades' values of air temperatures**. Also, 2007 shows large differences between two periods (January - August is very warm period, where the period from September - December is cold.)

Figure 1b. Anomalies of decades sum of precipitation



Similar oscillations were detected in terms of precipitation (Fig 1b). We can see two extreme decades sum in Sarajevo: 185 mm (2th decade December 1999) and 172 mm (3th October 2003). Also, 2007 shows differences between two periods (January - August – with low precipitation, and period from September - December with higher precipitation.)

To determine intensity and number of these oscillations we applied these conditions: $t+sd$, $t+2*sd$, $t-sd$, $t-2*sd$, and we analyzed 396 values of decades temperatures from row 1997 – 2006 and 2007.

Tables 1a and 1b show results.

Table 1a Number of decades with average temperatures > t+sd or t-sd

	Warm	extreme warm	cold	Extreme cold
1997 - 2006	202,0	181,0	187,0	100,0
2007	83,0	93,0	101,0	78,0

However, due to the trend of global warming, the number of warm periods is increasing, and also a high number of cold periods is evident, which is indicated by the huge oscillations of temperatures.

To observe changes in precipitation regime we applied conditions > R+sd or R+2*sd, where R means average decades sums precipitation from row 1961 – 1990, and decades from row 1997 – 2006 and 2007.

Table 1b	Number of decades with precipitation > R+sd or R+2*sd	
	rainy	extreme rainy
1997 - 2006	55,0	19,0
2007	7,0	2,0

The data indicated a large variability in the rainfall regime, with increase in intensity and an increase of drought period.

Analyses of precipitations indicate a large number of decades sum characterized by extreme values. We observed increase in rainfall intensity over 1 day, 3 days and 5 days maximum precipitations. We associated linear trends in rows 1951-2006, for example:

Figure 2a

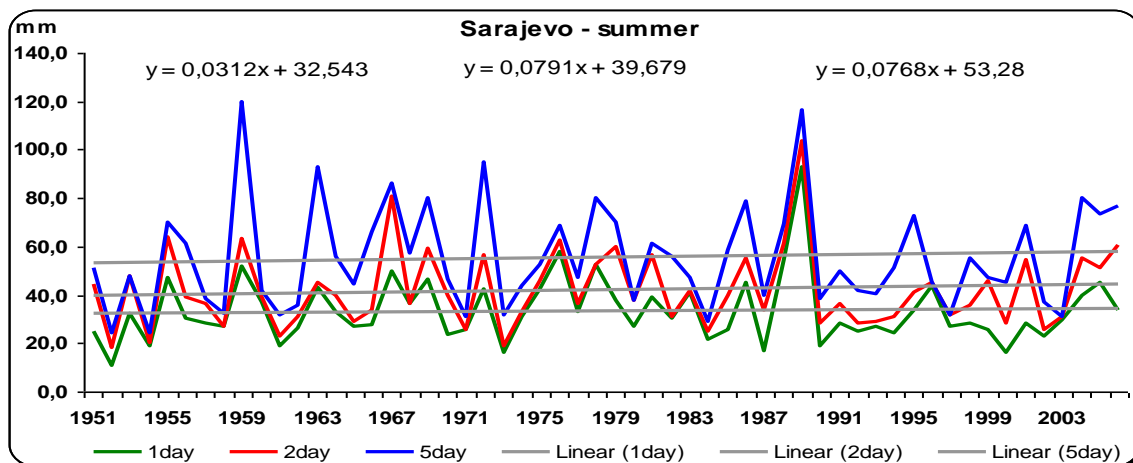
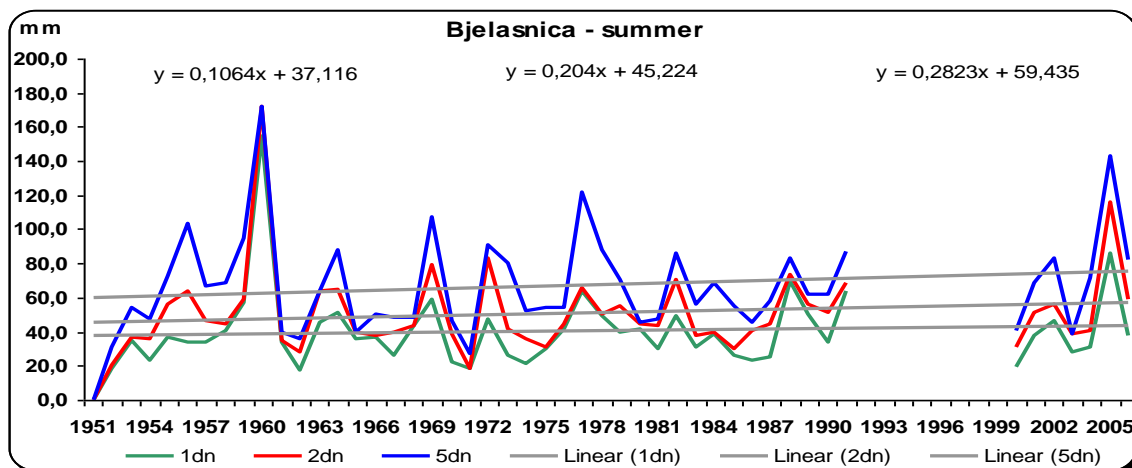


Figure 2b



AGROMETEOROLOGICAL CONDITIONS

Weather variability mentioned above also have influence on agrometeorological conditions. We considered two agrometeorological parameters: number of growing days and sum of effective temperatures. Both values are presented in tables 2 and 3.

Table 2 Length of growing days

	Sarajevo		Sanski Most		Mostar		Gradačac	
		Anomaly		Anomaly		Anomaly		Anomaly
1997	222	-28	256	1	335	2	291	27
1998	229	-21	236	-19	328	-5	296	32
1999	246	-4	252	-3	304	-29	259	-5
2000	268	18	287	32	321	-12	309	45
2001	257	7	261	6	326	-7	277	13
2002	297	47	297	42	331	-2	309	45
2003	254	4	259	4	320	-13	271	7
2004	246	-4	249	-6	327	-6	273	9
2005	233	-17	247	-8	298	-35	253	-11
2006	241	-9	261	6	331	-2	261	-3
2007	283	33	296	41	335	2	271	7
1961-1990	250		255		333		264	

As can be seen in Table 2 (Fig 2), during the period 1997 – 2006 the length of the growing season assumed different values. Anomalies were positive or negative, if we compare them with average values in the period 1961 – 1990.

Otherwise, if we compare sums of effective temperatures in the period 1997 – 2006 with average values of the same parameter in the period 1961 – 1990, in most cases anomalies were positive and the sums of effective temperatures were greater than average values.

In Sarajevo, six years out of the last eleven, presented shorter growing season compared to average values in the period 1961 -1990. At the same time in only two years out of the last eleven the sum of effective temperatures during the growing season was lower than average values.

In other stations, such as Sanski Most, Mostar and Gradačac, in the last eleven years, one (Mostar), three (Gradačac) and six (Sanski Most) years with shorter growing season compare with average value from

the period 1961 -1990 and each of them had only one year with sums of effective temperatures during the growing season lower than average values from the period 1961 – 1990.

Table 3 Sum of effective temperatures

	Sarajevo		Sanski Most		Mostar		Gradačac	
	Sum	Anomaly	Sum	Anomaly	Sum	Anomaly	Sum	Anomaly
1997	3079,4	-313,1	3434,1	-107,6	5313,0	152,5	4075,4	133,2
1998	3454,0	61,5	3642,4	100,7	5349,2	188,7	4335,1	392,9
1999	3579,8	187,3	3868,7	327,0	5396,9	236,4	4240,3	298,1
2000	4050,0	657,5	4244,9	703,2	5628,8	468,3	5044,4	1102,2
2001	3608,2	215,7	3850,1	308,4	5446,2	285,7	4407,7	465,5
2002	3959,2	566,7	4185,7	644,0	5569,7	409,2	4655,0	712,8
2003	3733,4	340,9	3999,6	457,9	5636,6	476,1	4481,9	539,7
2004	3488,5	96,0	3650,6	108,9	5316,6	156,1	4036,4	94,2
2005	3277,5	-115,0	3614,2	72,5	5025,3	-135,2	3838,0	-104,2
2006	3417,1	24,6	3803,7	262,0	5369,8	209,3	4333,2	391,0
2007	3882,9	490,4	4095,8	554,1	5694,5	534,0	4611,1	668,9
1961-1990	3392,5		3541,7		5160,5		3942,2	

Drought period have been defined using the De Martonne Index from the period 1997– 2006 and 2007, with average values of the same parameter from the period 1961 – 1990. Results show unusual large number of drought periods classified from moderate to extreme drought.

The De Martonne Index is also low in summer period especially for the southwest area of Bosnia and Herzegovina. (Table 4. a, b, c, d, e.)

We also analyzed the relationship between precipitation and evapotranspiration during the growing season for the period 1961-1990 and 2007 for **Northeast part of B&H (Gradačac - fig.3 a,b)**, which is well known as an area with a significant agricultural production.

Figure 3 a

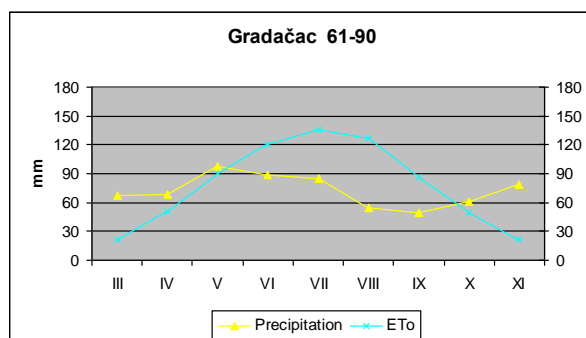
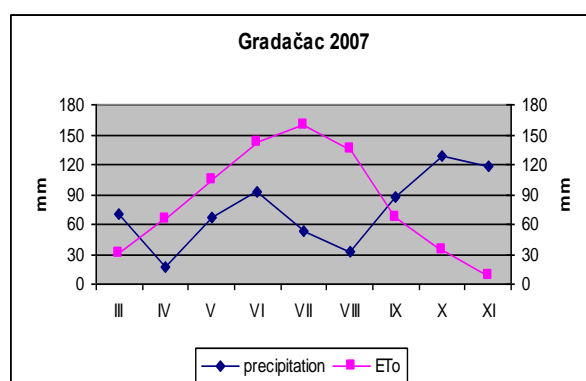


Figure 3 b



The results show an increased water requirement (relation between precipitation and evapotranspiration) in the 2007(3 b) especially from April to September compared to the period from 1961 to 1990(3.a). These results lead to the conclusion that climatic changes in the last period 1997 – 2006 caused increased water requirements for the crops grown, and thereby also higher water deficit in soil, increasing the demand for larger quantities of water suitable for irrigation.

Processing decade values, we also identified presence of cold and warm short period and large variability regime of precipitations. The above mentioned phenomenon had some influence on crop growing and development conditions, length of growing season, sum of effective temperatures, evapotranspiration and shortage of water in soil. Agrometeorological conditions showed a significant correlation with changes of basic climatological parameters caused by global warming.

Tables 4 (a,b,c, d,e,f):

a)

Sarajevo							
year	III	IV	V	VI	VII	VIII	IX
1997	37	88	29	20	33	23	9
1998	41	49	21	41	15	24	55
1999	44	58	30	31	40	33	47
2000	46	27	33	9	20	6	32
2001	42	74	34	54	26	28	121
2002	30	71	40	19	30	38	101
2003	2	20	22	38	25	3	38
2004	40	67	51	35	56	16	32
2005	69	43	54	35	44	61	49
2006	114	45	29	35	47	75	19
2007	55	11	51	23	25	10	75

b)

Gradačac							
year	III	IV	V	VI	VII	VIII	IX
1997	21	36	18	30	38	29	17
1998	35	17	37	48	44	24	61
1999	26	33	27	27	47	8	36
2000	28	15	20	7	12	2	15
2001	41	54	31	106	24	6	116
2002	16	55	49	24	19	33	38
2003	9	7	14	18	23	10	32
2004	14	96	42	39	37	14	27
2005	45	47	30	39	61	63	22
2006	64	60	32	46	12	62	10
2007	44	9	29	34	18	12	41

c)

Sanski Most							
year	III	IV	V	VI	VII	VIII	IX
1997	38	87	30	46	41	27	25
1998	38	57	56	31	18	17	86
1999	22	63	34	45	46	13	52
2000	50	29	32	11	40	1	36
2001	39	69	16	65	21	3	141
2002	19	100	80	24	13	52	90
2003	29	14	25	17	26	9	59
2004	67	94	38	48	34	14	46
2005	58	37	40	30	42	62	39
2006	80	78	42	42	9	73	19
2007	56	9	74	38	19	31	102

d)




Mostar							
year	III	IV	V	VI	VII	VIII	IX
1997	7	94	28	10	13	26	7
1998	9	66	47	22	7	21	135
1999	80	92	36	28	31	20	31
2000	38	33	22	5	24	5	26
2001	93	66	14	20	10	1	97
2002	26	65	39	15	23	61	82
2003	0	34	27	19	9	7	36
2004	112	71	70	29	10	35	22
2005	102	59	38	12	37	49	73
2006	83	46	31	31	7	46	53
2007	93	7	38	19	8	3	42

e)

61-90

De Martonne index	III	IV	V	VI	VII	VIII	IX
Gradačac	51	39	45	36	33	21	22
Mostar	90	66	44	30	16	25	38
Sarajevo-Bjelave	54	46	41	40	34	30	33
Sanski Most	59	53	48	44	40	38	37

Legend

	extremely drought month
	drought month
	semi drought month

CONCLUSIONS

Research on climate change conducted by the Federal Hydro Meteorological Institute in B&H showed the following results:

- Increase in annual average temperature from 0.7 °C to 0.8 °C in the last 100 years.
- No significant change in annual average precipitation;
- High frequency of records in absolute maximum temperature, but also records in the other meteorological parameters (minimum temperatures, maximum daily, decade, and monthly precipitation sum, intensity of precipitation, frequency of long and short dry periods).
- Weather variability, in short time intervals, and on small space, were also noticed, as well as bad bio-meteorological condition and troubles in agriculture (increased water requirement of the crops grown, and thereby also higher water deficit in soil and a higher demand for suitable irrigation water).
- No catastrophes, natural disasters, human losses, or significant material damage, unlike other parts of the world.
- Posavina (in north part B&H) can be treated as risky place for flooding and drought, and Herzegovina (in south-west part B&H) can be treated as a risky place for forest conflagration and drought.

REFERENCES:

- Zeljko Majstorovic, Sabina Hodzic, Nedžad Voljevic, AGROMETEOROLOGICAL CONDITIONS IN BOSNIA AND HERZEGOVINA, BALWOIS 2008, Ohrid, 23-27 May, 2008
- Auer, I., R. Böhm, A. Jurkovic, W. Lipa, A. Orlik, R. Potzmann, W. Schöner, M. Ungersböck, C. Matulla, K. Briffa, P. Jones, D. Efthymiadis, M. Brunetti, T. Nanni, M. Maugeri, L. Mercalli, O. Mestre, J.-M. Moisselin, M. Begert, G. Müller-Westermeier, V. Kveton, O. Bochnicek, P. Stastny, M. Lapin, S. Szalai, T. Szentimrey, T. Cegnar, M. Dolinar, M. Gajic-Capka, K. Zaninovic, Z. Majstorovic, and E. Nieplova (2007), HISTALP - HISTORICAL INSTRUMENTAL CLIMATOLOGICAL SURFACE TIME SERIES OF THE GREATER ALPINE REGION, *International Journal of Climatology*, 27(1), 17-41.(2007)
- Dženan Zulum, Zeljko Majstorovic:** IMPACT OF CLIMATE CHANGES IN PRECIPITATION REGIME IN B&H, Environmental impacts and challenges of climate changes, Sofia, May 2008
- Zeljko Majstorovic, Sabina Hodzic, Dzenan Zulum: EXTREME EVENTS AND WEATHER VARIABILITY IN BOSNIA AND HERZEGOVINAWITHIN LAST TEN YEARSWITH SPECIAL OVERVIEW ON 2007. , Environmental impacts and challenges of climate changes, Sofia, May 2008
- Z.Majstorovic: REFLECTION OF GLOBAL CLIMATIC CHANGES ON TERRITORY OF BOSNIA AND HERZEGOVINA, IUGG Conference Perugia 2007.

ECOLOGICAL CHALLENGES AND INVESTIGATIONS IN THE FOREST FUND OF BULGARIA

Ivan Ts. Marinov
Forest Research Institute – BAS – Sofia
Email: marinbg@bas.bg

Summary: Degradation processes in forest soils (erosion, heavy metals pollution, acidification), as well as the influence of biotic and abiotic factors (pests and diseases, forest fires, unadjusted anthropogenic activity), are the main ecological problems for Bulgarian forests. This paper presents results from investigations in the forest fund concerning these problems. The main degradation process in the forest soils is soil erosion - the whole classified eroded soils are above 7.0 % of the forestlands. Instead, during the last two decades heavy metal concentration in forest soils and lands decrease due to a reduction in the industrial activity, and only vegetation in proximity of local sources of pollution is mainly affected. Fires have affected a considerable portion of forested lands during the last two decades. This paper illustrates results of investigations carried out in the main experimental ecological stations of the forest lands in Bulgaria.

Key words: forest fund, degradation processes, ecological stations, Bulgaria

INTRODUCTION

The forest fund (forestlands) of Bulgaria covers 4,064 million ha, of which 3,648 million ha are under vegetation (source of data - National Forestry Board 2004), 511,000 ha are reconstruction forests and 109,000 ha are areas without vegetation but subject to afforestation. The rarefied crops and natural vegetation of density up to 0.3 occupy 108,000 ha of the vegetated areas. The forest fund represents about 36.5 % from the territory.

The main ecological problems for Bulgarian forests are related to degradation processes in forest soils, including erosion, pollution and floods; influence of biotic and abiotic factors, including pests and diseases attacks, as all as anthropogenic activity on the forests, and degradation caused by forest fires.

ECOLOGICAL CHALLENGES IN THE FOREST FUND

Degradation processes in forest soils

The most widespread soils in Bulgaria, which cover around 60% of the territory, are Luvisols, Chernozems and Cambisols, according to the FAO classification. The degradation processes like erosion, pollution, acidification, salinization and fires lead to losses of the most fertile part of soils. As a result of these degradation processes, the productive potential of soil decreases, which also affects biodiversity of terrestrial ecosystems.

Soil erosion and floods

Soil erosion is the main degradation process and national problem in Bulgaria, with 1.5 million ha representing the total amount of unproductive land affected by degradation. About 800,000 ha of land are strongly eroded and unsuitable for agricultural crops. The potential yearly soil loss in about 61.6% of the territory of the country is more than 10 t/ha, and in about 30 % of the territory soil loss even exceeds 40 t/ha/year (Rousseva *et al.*, 2003).

In the past, large-scale erosion control measures have been adopted in forestlands. The National Long-Term Programme for Erosion Control was adopted in 1982. The activities in State Forestries were defined in the programme. It was stated that erosion processes affected 15 % of Bulgarian forestlands, and that there was a need for adopting anti-erosion measures in the hydrograph network in about 2,300 water flows in which the erosion processes had been developing.

In the past century, over 2,300,000 ha in the forestlands have been afforested, with 820,000 ha now providing some anti-erosion function. In addition, 618,000 m³ barrages (check dams) were built, together with 395,000 m³ of small-size dry-masonry thresholds, 600,000 m² of clay wattles and 429,000 m of side wattles.

Nowadays the problems of erosion in Bulgarian forestlands are still considerable. In many regions, erosion processes have decreased water retention and soil protection capacity of vegetation, and the soils have become heavily eroded. The completely classified eroded soils in the forest fund were about 292,000 ha at the end of year 2004 (Marinov & Bardarov, 2005). The largest areas affected by erosion are located in Regional Forestry Boards in Blagoevgrad, Kardzhali, Kyustendil, Sofia and Smolyan – being in total between 30,000 and 60,000 ha. The Regional Forestry Boards Blagoevgrad, Kardzhali, Kyustendil, Smolyan present the highest percentage of territory affected by erosion (from 12 to 17 %).

Many of the small rivers in Bulgaria have the characteristics of torrential rivers. Floods in these rivers and in the main rivers are becoming more and more frequent. Flood events have caused significant damages during the most recent years. From 1990 to 2001 about 440 torrential high stream flow events occurred in the main rivers and in their tributaries. The year 2005 was especially difficult since the damages exceeded 750 million euro and there were 25 human victims.

There were considerable **damages by torrential floods in Bulgaria's forest fund** in the year 2005. Funding anti-erosive afforestations, maintenance of road network and riverbeds has been insufficient during the last years. With the reduction of these preventive activities, the regulating function of forests on formation of maximal waters in riverbeds was reduced. As a result, significant damages affected infrastructure, erosion control facilities, forest plantations and nurseries. The current problems of erosion and torrential (flood) control in forest fund are the result of eroded lands, of insufficient capability of part of forest ecosystems to perform protective functions, of the emerging trend towards considerably reducing anti-erosion forestation, and of unfavourable global climate warming. It is necessary to solve these problems, which will allow the State Forestry Agency to adopt in the country measures consistent with the conventions for biodiversity conservation, for climate change and for combating desertification.

Heavy metals pollution

Results from long term monitoring (20 years) concerning heavy metal concentration in the forest soils showed that the degree of pollution decreased in the last years 20 years of monitoring, (Marinov *et al.*, 2005; 20 year monitoring, 2006), showing that condition of forest soils and lands is going to be improved. The main reason for that has been the decrease in industrial activity during last two decades. Vegetation in proximity of local sources of pollution is mainly affected. The content of heavy metals higher than the maximum permissible concentration (MPC) could be arranged in a descending order as follows: Cd, Pb, Zn, Cu. The main causes determining an excess of the MPC for Cu, Pb and Zn are local sources of pollution – mainly industries processing ferrous and non-ferrous metals, such as the Kremikovtsi Steel Works, Kardzhali, Pirdop, and Eliseyna. Increasing content of Cd during the recent years, especially in the regions of Western and Middle Balkan Mountain, as well as in the Rhodopes and Sakar Mountains, is mainly due to transport of fuel combustion.

Acidification

Many of the soils are genetically weak, with a tendency to be heavily acid. Soil acidification decreases their buffer capacities. For forest soils the critical loads for sulphur is exceeded in almost 48 % of the studied territory of the country (Ignatova *et al.*, 1998), while for nitrogen the situation is less critical. There are also significant concomitant changes in the acidity of forest litter.

In a previous paper (Marinov *et al.*, 2005), some recommendation were proposed to deal with this problem, i.e., developing: i) a program for reducing degradation processes ii) methods for assessment of organic matter losses and microbial potential of soils, iii) a mechanism for assessment of agroecological regions suitable for practicing organic agriculture, as part of the sustainable agriculture, and (iv) applying special trainings for knowledge improvement for preserving the soil resources.

Influence of biotic and abiotic factors

Almost 5 % of the total forest area is yearly influenced by biotic and abiotic factors, with a total surface of about 200,000 ha (Byalkov *et al.*, 2006).

A significant part of the investigations about biotic and abiotic influences has been performed in the frame of the "International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests". Information about the factors influencing forest condition was provided by long-term and large scale monitoring of the forest carried out for more than 20 years in Bulgaria in 256

plots along a grid net of 16x16 km, 8x8 and 4x4 km (20 years monitoring, 2006). The Forestry University and Forest Research Institute in Sofia carried out these investigations.

The long-time data collected about the health status of Bulgarian forest made it possible to understand the impact of different factors on the state of different tree species and stands (20 years monitoring..., 2006). Climate conditions (prolonged drought in the period 1982 – 2003) were found to be the main factor. In some areas pollution and development of biological pests affected the increase of damages and dryness. Drought over the 1982 – 1994 periods showed no substantial negative changes for the most natural forest of *Pinus silvestris* L., *Picea abies* L., *Fagus sylvatica* L. and *Pinus nigra* Arn. (Raev & Rosnev, 2004). However, *Abies alba* Mill., *Quercus petraea* Liebl. and *Quercus cerris* L. forests were considerably affected by drought, with physiological disturbances which are a pre-condition for greater damages of the forest stands from pests and diseases. In the recent years anthropogenic influences have also increased – illegal felling, fires, etc. and damages of abiotic character, such as local windthrows and snowbreaks.

Forest fires

Fires causing complete destruction of forest vegetation or damage in various degrees, with loss of organic matter, damage of the structure and subsequent erosion represent a considerable problem in Bulgaria. From 1988 to 2004, in the countries in Southeast Europe the yearly forested areas affected by fires was 156,361 ha (FAO Forestry paper 151, 2007). The largest areas burned in the year 2000. These fires were caused by humans, and no explanation were found.

The number of registered forest fires in Bulgaria has increased during the last two decades. In the period from 1991 to 2001, fires affected about 3.5 % of the forested lands. The analysis of fire related information shows that the Regional Forestry Boards (RFBs) arranged the degree of risk of fire in the following descending order: Kardzhali, Berkovitsa, Sofia, Burgas, Blagoevgrad, Lovech, Kyustendil and Pazardzhik (Velizarova *et al.*, 2006). Data related to fire's number and affected areas in Bulgaria for the period 1991 to 2005 show that the highest number of fires with the largest area affected occurred in 1993 and 2000 respectively - **1196 и 1710 fires and the largest areas in 2000 and 2001 – 57 406 ha and 20 150 ha** (Velizarova *et al.*, 2006).

Bulgaria has indeed received targeted support to improve forest fire management capabilities from some countries, organisations and the World Bank. In 2006, the European Twinning Project was developed for harmonising legislative, reporting and preventive measures with European Union standards.

It is necessary to enhance international cooperation in Southeast European region, concerning forest fire suppression, including development of standards and bilateral and multilateral agreements.

ECOLOGICAL INVESTIGATIONS

Considerable part of forest investigations is performed in permanent stations. Several ecological stations for climatic, hydrological, soil and erosion investigation, as well as health status of the stands, forest-regeneration, physiological and dendrochronological investigations have been established in Bulgaria. The main Stations are:

Ecological stations of Forest Research Institute – BAS – Sofia

Station 'Vasil Serafimov' - established in 1961 for complex investigations of representative forests of *Pinus silvestris* L. on the southern slopes of Rila Mountain from 1000 to 2000 m a.s.l. There are 4 research plots: young forest of *P. silvestris* L. at the age of 20-40; middle-aged forest of 50-70 and mature forest of 90-100, as well as a plot in the open air. There are also 3 experimental watersheds in forests of *Pinus silvestris* L.

Station 'Govedarts' - established in 1963 for investigations in representative forests of *Pinus silvestris* L. - 1250 m a.s.l., *Abies alba* Mill. and *Picea abies* L. - 1400 m, *Picea abies* L. - 1550 m, *Pinus mugo* Turra - 1800 m on the northern slopes of Rila mountain. There are 3 watersheds for the investigation of the chemistry of the river waters from 2600 to 1200 m. Total - 10 research plots.

Station 'Parangalitsa' - established in 1979 for the investigation of forests of *Picea abies* L. and *Abies alba* Mill. from the zone of their optimum in Europe - 2 research plots, 2 mountain watersheds with reserve regime: 1450 - 2500 m a.s.l. on the western slopes of Rila.

Station 'Balkanets'-established in 1970 in Central Balkan range for investigation of representative forests of *Fagus sylvatica* L. There are 6 research plots: young forest of *Fagus sylvatica* L., *Picea abies* L. and *Pinus silvestris* L. at about 50 years of age; mature forests of *F. sylvatica* L. at 160 years of age and control plots in the open air. There are two experimental watersheds in mature and young forests.

Station 'Devnya'-Suvorovo- established in 1975 for investigation of the effect of industrial pollution on forest ecosystems. At present it is closed.

Investigation in the stations include **climatic** parameters (air temperature, precipitations, solar radiation, speed and direction of the wind, air humidity), **hydrological** measurement (precipitations under the stands, runoff on the stems, surface water runoff, transpiration from the trees, total evaporation, soil moisture, river runoff, chemistry of the river runoff, snow cover), **soil** investigations (physical and chemical properties, chemical and mineralogical composition of the soil, soil microflora, soil pollution, lysimetric waters), **biometric** measurements and **other** investigations (health status of the stands, forest-regeneration, physiological and dendrochronological investigations) (Raev, 1994). Continuous and systematic investigations on **erosion processes in mountainous regions** in Bulgaria are under way in two experimental stations – 'Igralishte' and 'Gabra', situated at 850 – 900 m. a.s.l. (Mandev, 1984, 1995; Marinov, 2005).

Station 'Igralishte' - established in south western Bulgaria, Maleshevska Mountain, State Forestry 'Strumyani', near to village Igralishte. The investigations started in 1971. The experimental station includes four small watersheds. The investigations concern mainly water discharge and solid runoff. The forest vegetation is represented mainly by *Quercus petraea* Liebl., *Quercus fraineto* Ten., *Quercus pubescens* Willd. Two of the small watershed basins are planted with *Pinus silvestris* L. and parts of the others watersheds - with *Pinus silvestris* L. and *Pinus nigra* Arn.

Station 'Gabra' - established in Sredna Gora Mt. in 1973. The station is located on south-facing slope. The purpose of the investigations is to determine the dynamics of precipitations, interception, surface runoff, and soil losses for plantations of *Pinus silvestris* L. and *Pinus nigra* Arn. and for grass and fallow lands.

Ecological Stations of Forestry University – Sofia

Station 'Bazenika' – Yundola - established in 1964-65 for complex investigations on the role of forest ecosystems and of coniferous forest management in the Rhodopes Mountains in central-south Bulgaria (altitude - 1500 m). There are different watersheds with different densities of vegetation equipped with measuring systems for water and air temperature, precipitation (rain and snow), water discharge and total sediment load (Rafailova, 2003).

Station 'Barzya' - established in 1986 for complex investigations on the rate of natural recovery, the influence of logging on water supply, soil protective functions of forests, dynamics of heavy metal migration and air pollution in West Balkan Range (region of Petrohan, altitude – 1200 m). A need for new equipment for some investigations, as well as for resuming some suspended investigation in order to collect new data for current state of the forests and soil in result of the changes of climate and management techniques, emerged during last years.

CONCLUSIONS

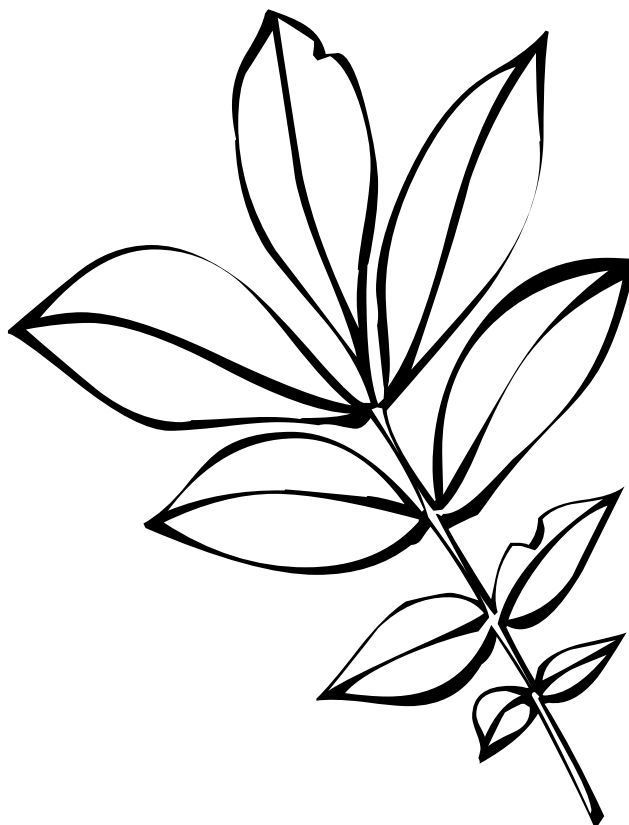
This paper presented some results from investigations in the forest fund concerning the main ecological problems for Bulgarian forests (degradation processes in the forest soils, influence of biotic and abiotic factors, forest fires). The main degradation process in forest soils is soil erosion. In the last two decades accumulation of heavy metal concentration in forest soils and lands has been reduced due to a decreasing industrial activity.

There are some damages and a considerable risk in connection with a continuous drought in the last years of the XX century. There are also other problems in Bulgarian forestlands such as illegal felling, fires, damages of local windthrows and snowbreaks. Fires have affected considerable part of the forested lands during the last two decades.

The paper also described activities carried out by the main experimental Ecological Stations of the Forest Research Institute and of University of Forestry in Bulgaria.

REFERENCES

- 20 year monitoring of the forests ecosystems in Bulgaria. 2006. In: *Assessment and monitoring of air pollution effects on forests. International co-operative programme "Forests"* (Editors: E. Pavlova, B. Rosnev), p. 23 – 219. (in Bulgarian).
- Byalkov, S., S. Balov, B. Rosnev. 2006. **Opportunity for improvement of the forests' condition.** In: *Assessment and monitoring of air pollution effects on forests. International co-operative programme "Forests"*, p. 16 – 22.
- FAO Forestry paper 151. 2007. Fire management – global assessment 2006. FAO. Rome, p.135. <http://www.fao.org/forestry/publications/en/>
- Ignatova, N., K. Jorova, M. Grozeva. 1998. Determination of critical loads for sulfur and nitrogen for forest soils in Bulgaria. In: *Proceedings Scientific papers Jubilee Scientific Conference with International Participation '70-th Anniversary of the Forest Research Institute'*, S., pp. 230-236. (in Bulgarian).
- Mandev A. 1984. A study on the water and solid flow in little catchments in Maleshevska mountain. *Forest Science*, 3, p. 45-64. (in Bulgarian).
- Mandev, A. 1995. Regularities in the variation of the intensity of sheet water erosion in upland watershed areas managed in a number of ways. In: *Proceedings of the Symposium on 90 years erosion control in Bulgaria*, Sofia, p. 37-42. (in Bulgarian).
- Marinov, I. Ts. 2005. Basic Results from Erosion Investigations in Mountainous Experimental Stations in Bulgaria. In: *Proceedings of the International Conference "Forest Impact on Hydrological Processes and Soil Erosion"*, 5 – 8 Oct 2005, Yundola, Bulgaria, p. 248 – 254.
- Marinov, I. Ts., D. Bardarov. 2005. Erosion state of soils in forestlands. *Forest Science*, 4 p. 69 - 78. (in Bulgarian).
- Marinov, I. Ts., S. Krastanov, E. Velizarova. 2005. Soils in Bulgaria – current state and degradation processes. – In: *Petrova, A. (Ed.), Current state of Bulgarian biodiversity – problems and perspectives. Bulgarian Bioplatform*, Sofia, pp. 469 – 484. (in Bulgarian).
- National Forestry Board –MAF. Annual reports. 2004. (in Bulgarian)
- Raev, I. 1994. Some results of long term station investigations in the forestlands of Bulgaria, carried out of Forest Research Institute – BAS. In: *National forestry and Ecosystems Monitoring Conference, Forest Research Institute, Ministry of Environment, Forestry Committee*; Sofia, pp. 149 – 182. (in Bulgarian).
- Raev, I., B. Rosnev. 2003. The Impact of Drought on Natural Forest Ecosystems. In: *Drought in Bulgaria: A Contemporary Analog for Climate Change (Edited by G. Knight, I. Raev, M. Staneva)*. Ashgate. pp. 117 - 136.
- Rafailova, E. 2003. Experimental hydrological stations in Bulgaria. In: *Proceedings of International conference "Natural and Socio-Economic Effects of Erosion Control in Mountainous Regions*, Belgrade. pp. 231 – 238.
- Rousseva, S., M. Banov, N. Kolev. 2003. Some Aspects of the Present Status of Land Degradation in Bulgaria. - In: *Johnes, R. & Montanarella, L. (Eds), The JRC Enlargement Action, Workshop 10-B, Land Degradation. EC-JRC*, 149-164.
- The State Agency "Civil defense". 1990 – 2001.** Annual Reports (in Bulgarian)
- Velizarova, E., I. Ts. Marinov, V. Konstantinov. 2006. Forest Fires – dynamics, assessment and ecological consequences. *Forest science*, 1, p. 75 – 91. (in Bulgarian).



ENVIRONMENTAL APPLICATION OF FOREST TREE SPECIES IN PHYTOREMEDIATION AND RECLAMATION

Andrej Pilipović, Saša Orlović, Vladislava Galović, Leopold Poljaković-Pajnik, Zoran Galić, Verica Vasić

University of Novi Sad, Institute of Lowland Forestry and Environment, Novi Sad, Serbia

Summary : This paper presents a short review about phytoremediation, its principles, mechanisms and possibilities of application. The paper also illustrates results of research conducted at the Institute of Lowland Forestry and Environment in Novi Sad, Serbia, using poplars and willows for phytoremediation. Information collected worldwide shows the great potential of using trees, especially poplars and willows in phytoremediation and their potential contribution for improvement of environment.

Keywords: phytoremediation, trees, poplars, willows

INTRODUCTION

Groundwater and soils can become contaminated as a (i) consequence of natural activities, such as geological erosions and salt drainage, or (ii) by human activities in industry, agriculture, wastewaters, constructions and mining. Contaminants can be both of organic and of inorganic origin (heavy metals, radionuclides, nitrates, and phosphates, inorganic and organic compounds) (Sparks, 1995). Processes of remediation by mechanically-physically-chemical techniques can be significantly expensive and, according to Schnoor (1997), their cost may range between 100 and 1500 US\$ per ton of soil, depending upon the selected technique. Phytoremediation can therefore represent a valid alternative to these techniques.

In the last decade of 20th century, American scientists developed research about plant-affectation on sites contaminated by heavy metals, organic and non-organic compounds produced by industry. Researchers showed plant-affectation in decrease of their concentrations in soil, surface and groundwater. This developed an idea for planting plants at these sites and the technique is called phytoremediation. Phytoremediation is an emerging technology that uses various plants to degrade, extract, contain or immobilize contaminants from soil and water (EPA, 2000).

PHYTOREMEDIATION

Phytoremediation is use of plants and their associated microorganisms for cleaning up the environment (Salt et al., 1995; Raskin et al., 1997). According to Salt (1995), one of the mechanisms of phytoremediation is phytodegradation, during which plants and their rhizospheric microorganisms degrade organic contaminants. Some authors (Arthur et al., 2005; Epa, 2000) consider degradation of contaminants by rhizosphere microorganisms as a separate mechanism called rhizodegradation.

In the northern hemisphere only a limited number of woody species are suitable for phytoremediation. Poplars (*Populus* sp.) and Willows (*Salix* sp.) are the most common tree species used for phytoremediation because they grow rapidly, have many and deep roots, and take up large quantities of water (Licht and Isebrands, 2005). They were originally bred and grown as a cash crop for use as pulp wood and as renewable energy source, but because of their rapid growth rates and high evapotranspiration rates, they can be considered as ideal candidates for phytoremediation (Chappell, 1997.) Their large root systems with a high proportion of fine roots (diameter smaller than 1mm) have a considerable ability of retaining large amounts of water in the vadose zone above the groundwater table, thus providing high transpiration rates (Quinn et al., 2001). This makes Poplars, especially with deep rooted planting (Ipc, 1979), especially suitable to be used as barriers to contaminant plume via groundwater. Various researches showed significant potential of Poplars for phytoremediation from different contaminants with use of different phytoremediation mechanisms like phytodegradation of VOCs (volatile organic compounds) (Newman et al., 1997; Xingmao and Burken, 2004), fertilizers and pesticides (Licht and Schnoor, 1993), rhizodegradation (Federle and Schwab, 1989) and phytoextraction (Banuelos et al., 1997; Pilipovic et al., 2005).

Researchers up to date defined various different systems of phytoremediation of soils and groundwater depending upon the way plants affect contaminants. According to environmental protection agency of United States of America (EPA, 2000), the following mechanisms of phytoremediation should be considered:

A) phytoextraction is the process of up-taking contaminants by plants roots and of trans-locating them to upper parts of plants. With plant harvesting, the contaminants are removed from the contaminated site, which is easier simpler than excavating and removing soil layers. This technology is used for phytoremediation of soils, sediments and sludges. In some cases plants that accumulated metal can be used as a source for food, e.g. plants grown on soils with high concentration of selenium (se) can be used for feeding of animals (Bañuelos et al., 1997).

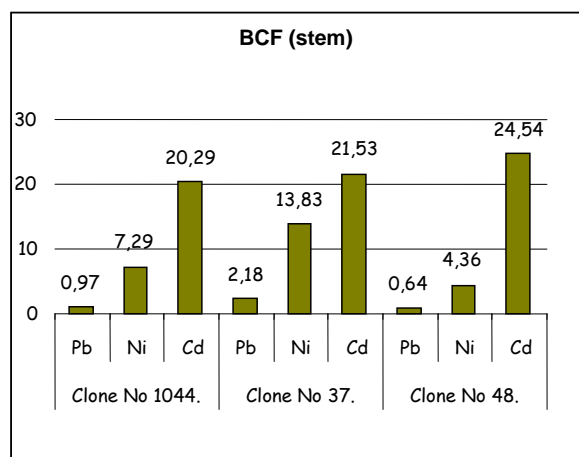


Figure 1. Phytoextraction potential of different Poplars (*Populus* sp.) Clones expressed through bioconcentration factor (ratio of concentration of contaminants in plant tissues and growing medium). Plants grown hydroponically showed high phytoextraction potential. (Pilipovic et al., 2005)

Disadvantage of this system refers to decrease of size and growth of plants, and biomass of roots due to the negative effect of heavy metals and possibility of phytotoxicity (Nanda Kumar et al., 1995). Also plants should be disposed by in special way, depending upon the treated metal.

B) Phytostabilization is the process of (1) immobilization of contaminants in soils by adsorption and accumulation in roots of plants or sedimentation root zone, (2) use of plants and plants roots to prevent migration of pollutants by wind and water erosion, drainage and dispersion in soils.

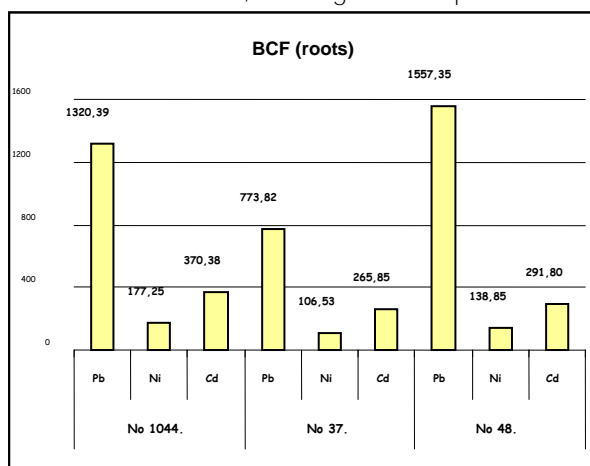


Figure 2. Bioconcentration factors of roots of different poplar clones shows phytostabilization of lead compared to nickel and cadmium (Pilipović et al, 2006)

Process of phytostabilization is carried out through the root zone, by microbiological and chemical mechanisms, with change of soil and/or contaminant chemistry. Due to the production of root exudates and CO₂, changes in pH value of soil are very frequent. Phytostabilization can change metal solubility, or affect solubility of organic compounds. Plant affected soils can transfer metals from insoluble to a soluble oxidizing state (Salt et al., 1995). In some cases, phytostabilisation can result in phytolignification, in which case organic matter is incorporated in plant lignin (Cunningham et al., 1995). Soils, sediments and sludges containing contaminants in the root zone can be treated with this mechanism, where influence of roots can be extended with transport of exudates to lower layers. Advantages of this mechanism is in situ treatment,

return of vegetation and unnecessary disposal of dangerous materials. Disadvantages of phytostabilization is represented by the fact that contaminants are not removed from site, and by the need for fertilizing in order to prevent drainage.

C) rhizodegradation is degradation of organic contaminants with microorganisms supported by presence of roots. This mechanism is also called biodegradation. Root exudates contain sugars, aminoacids, organic and fatty acids, sterols, growth hormones, enzymes and other compounds that stimulate development of microorganisms (Schnoor et al., 1995a).

Microorganism abundance and activity in the rhizosphere can be increased by presence of exudates, which can result in increased biodegradation. Also, the rhizosphere area can be increased by stimulated biodegradation. Biotransformation processes in the rhizosphere are the of consequence of secretion of enzymes by microorganisms amongst which, according to Coats (1991), there are oxidation, reduction, hydrolysis, conjugation etc. Interaction of plants and microorganisms also determines a mutual assistance, because microorganisms create better conditions for plants through detoxification of phytotoxic compounds, thus increasing availability of nutrients (Anhalt et al., 2000), and plants supply nutrients for microbic development through root exudates (Chappell, 1997).

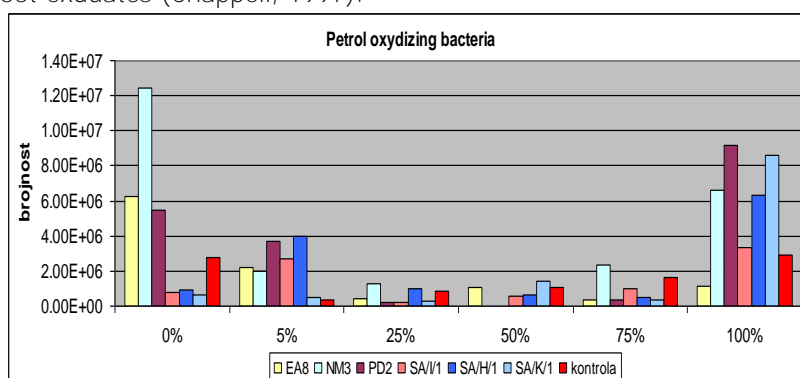


Figure 3. Rhizodegradation potential of different poplar clones grown on silos with different volume share of crude oil contaminated containing 10,8 mg/kg tph (pilipović et al., 2008)

Contaminants treated with this mechanism are carbohydrates, polycyclic aromatic carbohydrates, btx compounds (benzene, toluene, ethyl benzene and xylene) pesticides, chlorinated solvents etc. Advantage of this mechanism is **the "in situ"** treatment, which minimizes possibility of translocation for contaminants into the plants and atmosphere, and improvement of soil properties through mineralization. Disadvantages of this method is the long time needed for development of plants roots, especially in case of heavy clay soils and when depth of roots may affect the size of the affected zone.

D) phytodegradation (phytotransformation) is degradation of contaminants carried out by **plants'** metabolism. Main mechanism in this process is uptake and metabolizing of contaminants by plants. Uptake of contaminants depends upon their solubility, hydrophobic and polarity. Moderately hydrophobic compounds are easily uptaken, while highly hydrophobic organic contaminants are most often sedimented on root surface and rarely translocated, together with highly soluble compounds (Schnoor et al., 1995b). Non polar molecules with $m_r < 500$ will be bounded to root surface, while polar molecules will be uptaken and translocated (Bell, 1992). Advantage of this mechanism is possibility of application in solis without suitable microflora, while disadvantage is possibility of presence of toxic metabolites and intermediary products of metabolism.

E) phytovolatilization is process of uptake of contaminants by plants and their transpiration into the atmosphere, unchanged or slightly modified, where they are then degraded by solar radiation. In concomitance with this process, rhizo- and phytodegradation can also occur.

This method is used for groundwaters, for soils, sediments and sludge with sufficient hydraulic conductivity, in which the amount of transpired contaminants is strongly affected by climatic conditions (temperature, precipitation, insolation and wind). In case of partial degradation, there is a possibility of photodegradation by the sun (Chappell, 1997). Disadvantage is that transpired contaminants such as vinyl-chloride are cancerogenous and is a product of trichlor-ethene. Another disadvantage can be the potential accumulation of contaminants in plants and their fruits.

F) hydraulic control presents system of phytoremediation in which plants uptake groundwater and control contaminant plume and also called phytohydraulics. This mechanism is used for phytoremediation of surface and groundwaters. Advantage is lower costs compared to pumping systems, but disadvantages reflects in dependence upon seasons changes, climate conditions and depth of penetration of roots.

G) vegetative cover is long life sustainable vegetation system that is used for covering of landfills and dangerous waste disposal sites. Plants can be either planted in the material and do the phytoremediation, or planted in soil cover above the material.

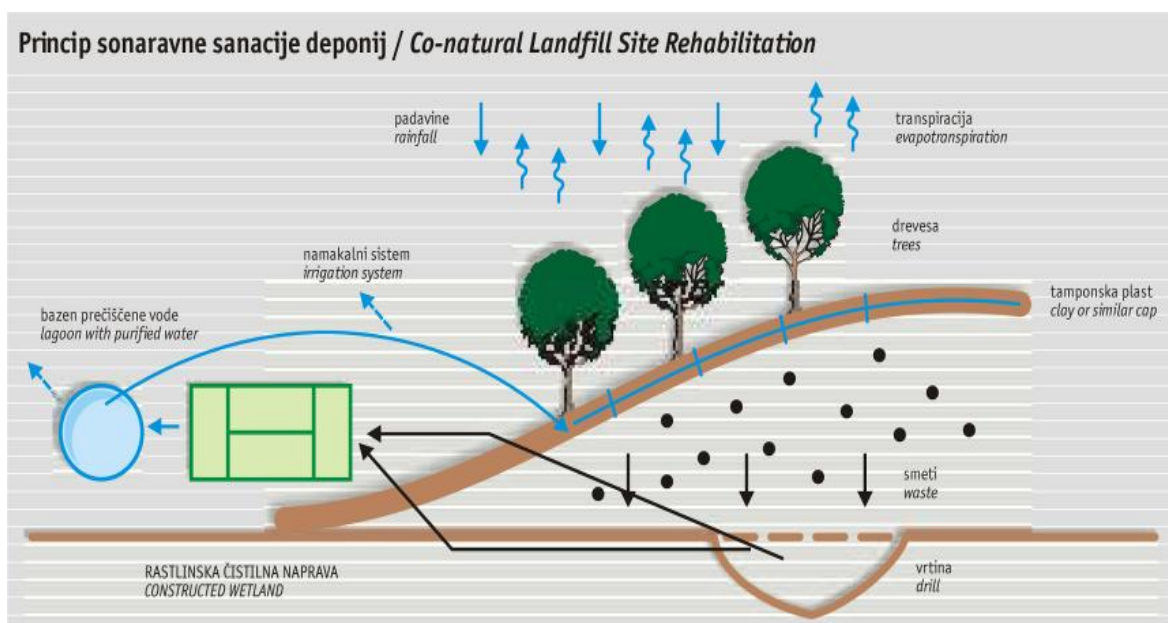


Figure 4. Example of vegetative cover in commercial use in Slovenia (Vovk Korže et al., 2007)

Both these two systems should prevent contact of human and animals with contaminated material and minimize water drainage and circulation through waste in order to prevent migration of contaminants. Advantage is erosion prevention and sustainability of these systems (Dwyer, 1997) and stimulation of microorganisms development. Disadvantage is possibility of water drainage through micro and macropores and accumulation of contaminants in plant tissues.

H) riparian buffers present multi row plantations of trees up to 50 meters wide. They are planted along watercourses in order to control surface runoff and clean up groundwater contaminated with nutrients and pesticides.

This mechanism is mixture of water uptake, contaminant uptake, plant metabolism, rhizo- and phytodegradation, phytovolatilization and phytoextraction. Disadvantage of this model is the fact that it can be applied only for easy assimilating and metabolizing components like fertilizers and pesticides that are very water soluble. Amongst the various number of contaminants present in the environment, nitrates play a significant role in ground and surface water contamination.

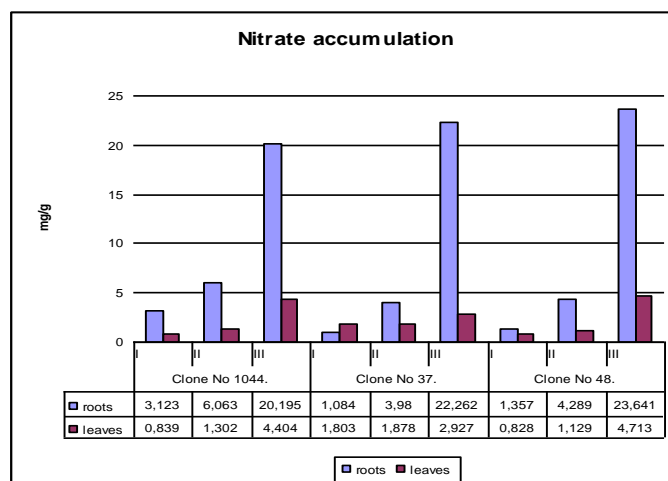


Figure 6. Potential of different polar clones grown hydroponically in uptake of nitrates from nutrient solution. Marks i, ii and iii present nitrate concentrations of 2, 10 and 30 ppm of nitrates/l. (pillipović, 2005)

Clean and safe drinking water is reasonably considered to be a basic human right, and water quality will undoubtedly be one of the most important ecopolitical issues in the coming decades (Landis et al., 1992). According to Newbould (1989), if nitrates present in drinking water are converted to nitrites they can cause methemoglobinemia in infants, while their excess in surface waters, together with phosphorus, can cause eutrophication. This contamination is mainly caused by agriculture, and increase of fertilization with mineral fertilizers plays a significant role in increase of nitrate concentrations both in plant tissues and environment (Kastori and Petrović, 2003). Also, excess of nitrates in soils enlarges their denitrification and emission of nitrous oxides such as N_2O , which provokes up to 300 times more harmful effect than CO_2 (Schepers et al., 2005)

CONCLUSIONS

The significant role of trees in phytoremediation is illustrated in this paper both through review of references and through results of research conducted at the Institute of Lowland Forestry and Environment. Plant roots can penetrate through deeper soil layers and remediate wider area. Their higher biomass, compared to herbaceous plants, can extract greater amounts of contaminants, providing great environmental benefit such as carbon sequestration, oxygen production and microclimate improvement.

REFERENCES

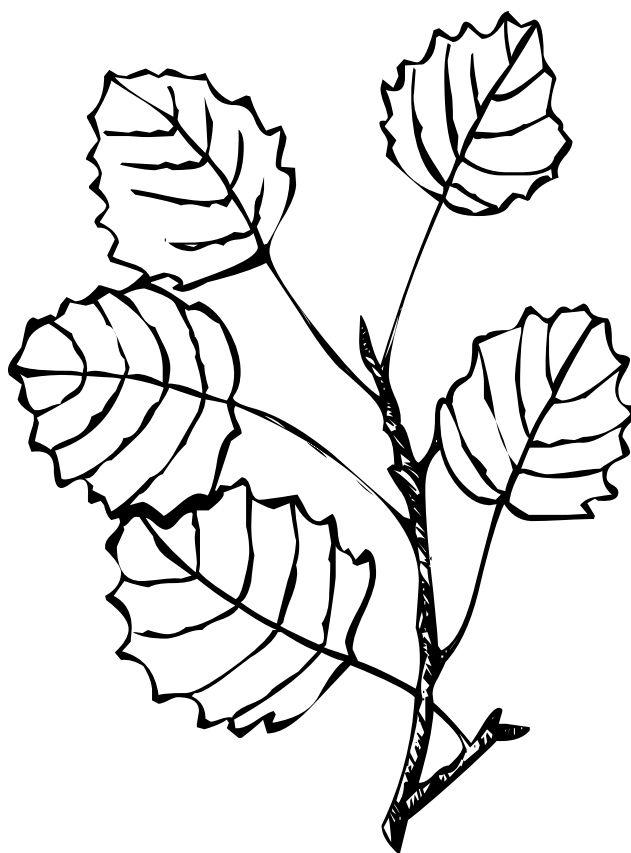
- Anhalt, J.C., Arthur, E.L., Anderson, T.A., and Coats, J. R. (2000) Degradation of atrazine, metolachlor, and pendimethalin in pesticide-contaminated soils: effects of aged residues on soil respiration and plant survival. *J. Environ. Sci. Health b*. 35: 417–438.
- Arthur, E.L., Rice P.J., Anderson, T.A., Baladi, S.M., Henderson, K.L.D., Coats, J.R. (2005) Phytoremediation-an overview. *Critical reviews in plant science.*, 24: 109-122.
- Bañuelos, G. S.; Ajwa, H. A.; Mackey, B.; Wu, L. L.; Cook, C.; Akohoue, S.; Zambrzuski, S. (1997) Evaluation of different plant species used for phytoremediation of high soil selenium. *Journal of environmental quality*, 26,639-646.
- Bell, R. M. (1992) Higher plant accumulation of organic pollutants from soils. Risk reduction engineeringlaboratory, Cincinnati, Ohio. Epa/600/r-92/138
- Chappell, J. (1997) Phytoremediation of tce using populus. Status report prepared for the US epa technology innovation office under a national network of environmental management studies fellowship compiled June - August 1997.
- Coats, J.R. (1991) Pesticide degradation mechanisms and environmental activation. In: somasundaram, I., and coats, j. R. (eds.): pesticide transformation products: fate and significance in the environment. Pp. 10–29., American Chemical Society Symposium Series 459, Washington, D.C.
- Cunningham, S.D.; berti, W.R.; Huang, J.W. (1995) Phytoremediation of contaminated soils. *Trends in biotechnolgy* 13, 393-397.

- Dwyer, S. F. (1997) Large-scale field study of landfill covers at sandia national laboratories. Conference proceedings landfill capping in the semi-arid west: problems,perspectives, and solutions, May 21-22. Grand tetonnational park, wy, 87-107.
- Epa/600/r-99/107. (2000) Introduction to phytoremediation, u.s. environmental protection agency, national risk management research laboratory office of research and development cincinnati, ohio 45268. February 2000
- Federle, T. W., and b. S. Schwab. (1989) Mineralization of surfactants by microbiota of aquatic plants. Appl. Environ. Microbiol. 55:2092-2094.
- International poplar comission (1979) poplars and willows in wood production and land use. 328 pp. Rome, Italy. Food and Agriculture Organization
- Kastori r.; **Petrović, n. (2003)** Nitrates in vegetables: physiological, ecological and agrotechnical aspects; **naučni institut za ratarstvo i povrtarstvo** - novi sad; verzal, novi sad, jugoslavija (Serbian with English summary)
- Landis, T. D.; Campbell, S.; Zeusen, F. (1992) Agricultural pollution of surface water and groundwater in forest nurseries; proceedings, intermountain forest nursery organization, USDA Forest Service, gen. Tech. Report 2, August 12-16, 1991, Park City, Utah, USA, 1-15.
- Licht, L. A.; Schnoor, J. L. (1993) Tree buffers protect shallow ground water at contaminated sites. Epa ground water currents, office of solid waste and emergency response. Epa/542/n-93/011.
- Licht, L.A., Isebrands, J.G. (2005) Linking phytoremediated pollutant removal to biomass economic opportunities , biomass and bioenergy 28: 203-218
- Nanda Kumar, P.B.A.; Dushenkov, V.; Motto, H.; Raskin, I. (1995) Phytoextraction: the use of plants to remove heavy metals from soils. Environmental science and technology 29(5),1232-1238.
- Newbould, P. (1989) The Use of nitrogen fertilizer in agriculture. Where do we go practically and ecologically?. Plant and soil 115, 297-311
- Newman, L.A.; Strand, S. E.; Domroes, D.; Duffy, J.; Ekuan, G.; Karscig, G.; Muiznieks, I. A.; Ruszaj, M.; Heilman, P.; Gordon, M.P. (1997) Abstract: Removal of trichloreth-ylene from a simulated aquifer using poplar. Fourth international in situ and on-site bioremediation symposium, April 28 - May 1, 1997, New Orleans, la. 3: 321.
- Pilipović, A** (2005) The role of poplars (populus sp.) In phytoremediation of nitrate contaminated waters ; m.sc. Thesis; University of Novi Sad, Faculty of Agriculture, Novi Sad, Serbia
- Pilipović, A., Nikolić, N., Orlović, S., Petrović, N., Krstić, B. (2005)** Cadmium phytoextraction potential of polar clones (populus spp.). Z. Naturforsch. 60c: 247-251.
- Pilipović, A.; Nikolić, N.; Orlović, S.; Krstić, B.; Rončević, S. And Borišev, M. (2008)** The effect of crude oil contaminated soil on growth of different populus sp. And salix sp. Genotypes. , 2nd international **scientific conference "remediation in environmental protection – present state and future prospects"**, Belgrade, Serbia May 14-15, 2008, proceedings book, pp 29-37.
- Pilipović, A.; Nikolić, N; Orlović, S.(2006):Reriew** of researches conducted on heavy metal and nitrate phytoremediation with use of poplars. Proceedings of scientific gathering implementation of remediation in environmental improvement with international participation, belgrade, november 27th 2006.(ed. **Ljiljana tanasijević**), ISBN 86-80809-32-2, pp 55-65
- Quin, J.J.; Negri, M.C.; Hinchman, R.R.; Moos, L.P. And Wozniak (2001) Predicting the effect of deep-rooted hybrid poplars on the groundwater flow system at a large-scale phytoremediation site. International juornal of phytoremediation; vol. 3, no.1, pp. 41-60
- Raskin, I., Smith, R.D., Salt, D.E. (1997) Phytoremediation of metals: using plants to remove pollutants from the environment. Curr. Opin. Biotechnol. 8: 221-226.
- Salt, D.E., Blaylock, M., Kumar, N.P.B.A., Dushenkov, V., Ensley, B.D. (1995) Phytoremediation: a novel strategy for the removal of toxic metals from the environment using plants. Biotechnology. 13: 468-474
- Salt, D.E., Smith, R.D., Raskin, I. (1998) Phytoremediation. Annu.rev. Plant physiol. Plant mol. Biol. 49: 643-668.
- Schepers, J.S.; Francis, D.D.; Shanahan, J.F. (2005) Relay cropping for improved air and water quality. A journal of biosciences, zeitschrift fur naturforschung c, I 60 (3/4), 186-190.
- Schnoor J.L. 1997: Phytoremediation. Groundwater technology analysis center: technology evaluation report te-98-01.
- Schnoor, J. L.; Licht, L. A.; Mccutcheon, S. C.; Wolfe, N. L.; Carreira, L. H. (1995a) Phytoremediation of organic and nutrient contaminants. Environmental science and technology 29, 318-323.
- Schnoor, J. L.; Licht, L. A.; Mccutcheon, S. C.; Wolfe, N. L.; Carreira, L. H. (1995b) Phytoremediation of organic and nutrient contaminants. Environmental science and technology 29, 318-323

Sparks, D.L.(1995) Environmental soil chemistry. Academic Press, San Diego, CA, USA

Vovk **Kože, A.; Vrhovšek, D. (2008) Ecoremediatioan** as strategic development approach, 2nd international scientific conference "Remediation in environmental protection – present state and future prospects", Belgrade, Serbia, May 14-15, 2008, proceedings book, pp 109-119.

Xingmao, M. And Burken, J. (2004) Modeling of tce diffusion to the atmosphere and distribution in plant stems. Environmental science and technology 38, 4580-4586



THE ROLE OF BIOTECHNOLOGY IN CREATION PLANTS FOR CHANGED ENVIRONMENT

Vladislava Galović, Orlović S., Pilipović A., Vasić V., Poljaković-Pajnik L., Galić Z.

Institute for Lowland Forestry and Environment, Antona Čehova 13, 21000 Novi Sad, Serbia

Summary: Due to rapid deforestation and depletion of genetic resources coupled with escalating human needs, there is a great need to conserve and improve tree ecosystems in general and their biodiversity in particular. To circumvent time consuming processes and low productive conventional tree breeding impediments (long generation cycles, high background polymorphisms, long-lived, large sizes, outcrossing systems of mating, near-isogenic lines, large experiments difficulties, slow growing, sexually self-incompatible, highly heterozygous (high genetic load also inbreeding depression), future research will employ modern techniques in forest breeding activities. Building up biotechnological approaches considering *in vitro* regeneration, mass micro propagation techniques and gene transfer studies in tree species can bring several benefits to dissection of adaptive traits: dominant mutations, strong alleles and simpler gene identification. Considering genus *Populus* as a model system, our research goals will be to develop transformation – based approaches that will reveal brighter insights into the genes that control adaptive traits and their functional characterisation.

This paper will introduce the up-to-date biotechnology techniques that mark most of the worldwide research work on trees. Introducing these novel technologies it is possible to change the tree genome towards adaptation to environmental change.

Key words: *climate change, populus, biotechnology, genetic transformation*

INTRODUCTION

Poplar

Genus *Populus* belongs to the willow, family *Salicaceae*, and contains at least 35 species of trees, together with a number of natural hybrids. Black poplar species (*Populus nigra* L.) have a wide geographical distribution ranging from Central and South Europe to Central Asia and North Africa (Zsuffa, 1974). It is a pioneer tree species of riparian ecosystems and there, in softwood floodplain forests, represents a keystone species as it is highly adapted to water dynamics and sediment movement (Storme, submitted publication).

As a fast growing species, *Populus* has become a tree of prime economic importance worldwide due to easy clonal propagation and to strong heterosis upon interspecific hybridization. As a consequence *P. nigra* plays a central role in poplar breeding programs and has contributed to many successful interspecific hybrids (Frison, 1995, and Weisgerber, 2001) together with species native from Europe or North America such as *P. deltoides* and *P. trichocarpa*. Because of its small genome size and its suitability for genetic transformation, poplar has become a model system for fundamental research on trees (Stettler *et al.*, 1996). In 2004 the entire genome of a female *Populus trichocarpa*, named Nisqually-1, has been sequenced. The draft sequence is now publicly available (www.genome.jgi-psf.org/poplar0/poplar0.home.html) and the International Populus Genome Consortium (IPGC) has been founded to help guide post-sequencing activities in poplar (www.oml.gov/ipgc/). So far **researchers have revealed poplar's genome to be about one-third heterochromatin**, that is, regions of chromosomes thought to be genetically inactive, which should provide shortcuts to important regulatory features. (www.genome.jgi-psf.org/poplar0/poplar0.home.html)

Endangered species

In the last centuries, large areas of its natural habitat have been lost due to changes in the management of riverbanks involving drainage, more intensive grazing and more frequent felling of trees (Lefevre *et al.*, 1998). Also, the intercrossing events with wild *P. nigra* trees suggest the major threat with extinction of this species. The autochthonous species *P. nigra*, is additionally endangered by intercrossing events with other species of the section *Aigeiros*.

In the past 50 years, in order to optimize the genetic diversity and enable them to adapt to changing environmental conditions, gene bank collections for *P. nigra* have been set up in most European countries mainly for breeding purposes (Heinze, 1997; Cottrell *et al.*, 2002).

GENETIC VARIABILITY OF THE TREES

A vital component of biodiversity

Preserving genetic variability is the main task for maintenance of the adaptive potential in species. Reliable information on the distribution of genetic variation is a prerequisite for selection, breeding and conservation programmes for forest trees. Until recently, field and laboratory techniques employed morphological and biochemical markers in order to estimate genetic diversity and mating system parameters from population surveys. Environmental influences on morphology and phenotype differences between juvenile and mature characters make it difficult to discriminate between genetically different individuals on the basis of morphological characters alone.

Biochemical and molecular markers were turned out to be the most suitable markers in order to detect hybrids and duplicated accessions and to establish the extent of genetic variation (Galović, in press) and the levels of heterozygosity (Karp *et al.*, 1997). Isozymes have been used in several studies of black poplar and they have been successful in distinguishing the different populus species and their hybrids (Legionnet *et al.*, 1997, Janssen 1997, Heinze, 1998.).

However, morphological markers proved to be difficult to be used in forest genetics due to different reasons. One reason is that they are recessive in nature, therefore heterozygotes are not identifiable. Those markers are generally mutations and they often confer a deleterious phenotype to the organism. They also exhibit epistatic effect or pleiotrophy. Their expression may be affected by environmental conditions and also confer a phenotype that is only apparent at one stage of an **organism's** development.

Meanwhile, application of the isozymes, as biochemical marker, also proved to have limitations, due to the number of enzyme loci, to the relatively low levels of variability and to the fact that they only reveal variation in protein coding genes and that only a minor proportion of modifications of the quaternary structure of the proteins can be detected.

Due to recent developments in the field of molecular genetics, a variety of different techniques has been created in order to reveal genetic variation on molecular level (Galović and Orlović, 2007). Since the advent of recombinant DNA technology in population genetics in the mid - **1980's**, the number of genetic markers available for population genetic studies of forest tree species has considerably increased.

Development of DNA markers has overcome the limitations on the number of variable loci, providing the tools to study variation in coding, non-coding and highly variable regions of both nuclear and organelle (chloroplast and mitochondrial) genomes.

Organelle genomes and highly variable genetic markers proved to be very useful (with different efficiency) and highly informative in the phylogeographic studies and analyses of phylogenetic relationships. Also, in tree population structure, mating system as well as gene flow, parental assignment, introgressive hybridization, marker-aided selection and genetic linkage (Vendramin and Hansen, 2005).

But all those markers are not useful for measuring adaptive genetic diversity (Krutovsky, Neale, 2005). The ideal marker for estimating adaptive variation should be directly involved in genetic control of adaptive traits, should be able to identify DNA sequence and its function and also allelic variation. A promising new marker satisfying most or all of these criteria recently emerged as a result of new, modern science – genomics, named expressed sequence tag polymorphisms (ESTPs). At present ESTPs stands for the most informative marker system in terms of gene function among the most recently developed one.

In forest genetics, not much is discussed of genomics as a new science that studies the whole genome by integrating traditional genetic disciplines such as population, quantitative and molecular genetics with new technologies in molecular biology, DNA analysis, bioinformatics and automated robotic systems.

A number of genomics sub-disciplines such as structural, functional, comparative, statistical and associative genomics can be combined to provide a powerful approach to studying adaptive genetic diversity broadly. Thus, genetic conservation and adaptive genetic diversity can benefit from new achievements in genomics.

APPLICATIONS OF BIOTECHNOLOGY TO TREES

Due to recent developments in the field of molecular genetics, a variety of different techniques has been created in order to reveal genetic variation on molecular level: tissue culture, protoplast fusion and "*in vitro*" selection, molecular markers, genomics, genetic transformation.

Tissue culture

Biotechnological approaches for in vitro regeneration, mass micro propagation techniques and gene transfer studies in trees species have been promising, particularly in the last decade. This technique offers an important option for effective multiplication and improvement within a limited time frame especially for difficult and recalcitrant species like trees.

Tissue culture has different utilities considering commercial aspect in which micro propagation is employed and indirect aspect like somatic embryogenesis and genetic transformation. Micro propagation of tree species offers a rapid means for producing clone planting stock for forestation programs, woody biomass production and conservation of elite and rare germplasm (Giri et al., 2004).

Somatic embryogenesis has been used for mass scale propagation and genetic transformation. It is of great importance in forestry biotechnology because this system offers the capability to produce an unlimited number of somatic embryos derived propagules, and can be efficiently used for genetic transformation studies.

Development of "in vitro" plant regeneration protocols is a pre-requisite for genetic transformation studies. There are recent reviews (Pena and Seguin, 2001; Herschbach and Kopriva 2002, etc.) demonstrating transfer of chimeric genes to the recipient species through genetic transformation of forest trees. Giri et al., (2004), presented a comprehensive study on the development of in vitro regeneration protocols, genetic transformation studies and some recent novel approaches for genetic improvement of trees.

Genetic transformation

Since the initial application to plants, which started two decades ago (De Block et al., 1984), genetic transformation has become an indispensable tool in plant molecular biology and functional genomic research. More than 144 plant species have been successfully transformed, representing almost all major phylogenetic lineages of the plant kingdom (Busov et al, 2005).

Improvement of forest trees via conventional selective breeding are severely limited, but transgenic technology offers the opportunity to domesticate trees, to tailor their characteristics more closely to the requirements of commercial forestry and the end-user of forest products (Johnson and Kirby, 2001). Genetic transformation offers an attractive alternative to breeding because it provides the potential to transfer specific traits into selected genotypes without affecting their desirable genetic background.

The availability of the poplar genome sequence, along with its large expressed sequence tag (EST) databanks, similarity to other genomes, easy transformation and rapid growth, enable genetic approaches to be used not only for transformation in itself, but also for testing virtually any hypothesis of gene function. The coding regions of *Populus* and *Arabidopsis* and *Oryza* genomes show a considerable similarity, indicating that differences between these annual and perennial angiosperm life forms result primarily from differences in gene regulation. Thus, studies of *Populus* directly benefit from detailed functional genomic information generated for *Arabidopsis* and *Oryza*, enabling insights into tree development and ecophysiological adaptation of trees to the environment.

Benefits from the development of transgenic trees are expected from the improvement of traits resistant to stresses, biomass production, tree stature, pathogen – host interactions, flowering control-steril poplars, developing transgenic plants for efficient phytoremediation of xenobiotic pollutants, etc.

One of the first reported field trials with genetically modified forest trees was established in Belgium in 1988 and the characteristic evaluated was herbicide tolerance in poplars. Since then, there have been more than 200 reported trials, involving at least 15 forest species. More than 50% of the field trials have been performed with *Populus* species, and the main target trials are herbicide tolerance (31%) and insect resistance (14%).

According to Valenzuela et al.,(2006), until 2006 there is only one report on commercial-scale production of transgenic forest trees which is *Populus nigra* with the Bt gene released in China in 2002 and established on commercial plantations in 2003.

TRANSGENIC EVENTS UP TO DATE

This paragraph mentions some of the up to date transgenic events that obtained plants suitable for practical application in changing environmental conditions. Gullner and colleagues (2001), succeeded in enhancing tolerance of transgenic poplar lines to chloroacetanilide herbicide **by overexpressing γ -ECS** in the cytosol (11ggs) or in the chloroplasts (6Lgl). By this way they increased the **levels of γ -ECS** and GSH in

leaves of each poplar lines and make them good candidates for phytoremediation purposes and for improving their detoxification capacity.

Several Arabidopsis homeotic genes that are involved in flower initiation induce early flowering when expressed ectopically in transgenic plants. One of them, LEAFY (LFY), has also been demonstrated to function in distantly related species, including hybrid aspen. Instead of flowering after 8-20 years, transgenic aspen constitutively expressing LFY produced flowers after only 7 months of vegetative growth (Rottmann et al., 2000; Pena and Seguin, 2001).

As a part of the work, Busov et al. (2005) initiated transgenic studies to test the effects of different DELLA domain proteins in the regulation of dormancy, crown architecture and elongation. Overexpression of DELLA genes in transgenic poplars suggest that they play important roles in control of ecophysiological traits.

In order to remove pollutants with increased rates of metabolism through overexpression of cytochrome P450 2E1a as a key enzyme in the halogenated compounds metabolism, Doty and colleagues created transgenic poplar (*P. Tremula* x *p. Alba*) introducing transgene CYP2E1-78 (Eapen et al., 2007).

REFERENCES

- Busov B. V., Brunner M. A., Meilan R., Filichkin S., Ganio L., Gandhi S., Strauss H. S., 2005. Genetic transformation: a powerful tool for dissection of adaptive traits in trees. *New Phytologist*, 167: 9-18
- Cottrell, J.E., Tabbener, H.E., G.I. Forrest G.I., 2002: Distribution of variation in British black poplar: The role of human management. **IN: (eds BC van Dam, S Bordács) Genetic diversity in river populations of European Black poplar - implications for riparian ecosystem management.** Proceedings of an international symposium held in **Szekszárd, Hungary, from 16-20 May, 2001.**
- De Block M., Herrera-Esrella L., van Montagu M., Schell J., Zambryski P., 1984: Expression of foreign genes in regenerated plants and their progeny. *EMBO Journ.*, 3: 1681-1689.
- Eapen S., Singh S., D'Souza SF., 2007: Advances in development of transgenic plants for remediation of xenobiotic pollutants. *Biotechnology Advances*, 25: 442-451.
- Frison, E., Lefèvre F., De Vries S., Turok J., 1995: *Populus nigra* network. Report of the first meeting, 3-5 October 1994, Izmit, Turkey. IPGRI, Rome, Italy.
- Galovic V., Orlovic, S., 2007: Overview of DNA based studies of genetic variability in poplars. *Topola*, 179/180: 71-79.
- Giri CC., Shyamkumar B., Anjaneyulu C., 2004: Progress in tissue culture, genetic transformation and applications of biotechnology to trees: An overview. *Trees*, 18: 115-135.
- Gullner G., Komives T., Rennenberg H., 2001: Enhanced tolerance of transgenic poplar plants **overexpressing γ -glutamylcysteine synthetase** towards chloroacetanilide herbicides. *Journal of Experimental Botany*, 52(358):971-979.
- Heinze, B. (1997) *Populus nigra* in Austria: rare, endangered, not recognized? **IN: (Turok J., Lefèvre F., de Vries S. and Tóth B., compilers) Euforgen *Populus nigra* Network.** Report of the third meeting. 5-7 October 1996, **Sávár, Hungary.** Pp 34-41.
- Herschbach C., and Kopriva S., 2002. Transgenic trees as tools in tree and plant physiology. *Trees Struct. Func.* 16: 250-261.
- Johnson B., Kirby K., 2001: Potential impact of genetically modified trees on biodiversity of forestry plantations: global perspective. Proceedings of the First International Symposium on Ecological and Societal Aspects of Transgenic Plantations. pp. 176-186.
- Krutovsky K. V. and D. B. Neale, 2005: Conservation and Management of Forest Genetic Resources in Europe. Chapter 4: Forest genomics and new molecular genetic approaches to measuring and conserving adaptive genetic diversity. Arbora publishers, Zvolen.

- Lefèvre, F., Legionnet A., de Vries, S., and Turok J. (1998) Strategies for the conservation of a pioneer tree species, *Populus nigra* L., in Europe. *Genetics Selection Evolution* 30 (Suppl. 1): S181-S196.
- Pena L., Seguin A., 2001: Recent advances in the genetic transformation of trees. *Trends in Biotechnology*, 19(12): 500-506
- Rottmann WH., Meilan R., Sheppard LA., Brunner AM., Skinner JS., Ma CP., Cheng CP., Jouanin L., Pilate G., Strauss SH., 2000. Diverse effects of overexpression of *LEAFY* and *PTLF*, of poplar (*Populus*) homolog of *LEAFY/FLORICAULA*, in transgenic poplar and *Arabidopsis*. *Plant Journal*, 22:235-245.
- Valenzuela S., Balocchi C., Rodriguez J., 2006: Transgenic trees and forestry biosafety. *Electronic Journal of Biotechnology*, 9 (3): 335-339.
- Weisgerber H. and Y.F. Han, 2001: Diversity and breeding potential of poplar species in China, *Forest Chron.* 77: 227–237.
- Zsuffa, L., 1974: The genetics of *Populus nigra* L. *Annales Forestales* 6/2 Academia scientiarum et artium slavorum meridionalium, Zagreb.



FACTORS OF SOIL DEGRADATION IN SERBIA

Stanimir Kostadinov, Nada Dragović and Mirjana Todosijević

Faculty of Forestry, Belgrade University; Kneza Višeslava 1, 11030 Belgrade, Serbia
E-mail: kost@EUnet.yu

Summary: The main types of soil degradation in Serbia are soil erosion, chemical degradation, soil degradation by surface mining, soil salinization and physical degradation. Soil erosion causes the most serious degradation in soil. Practically all the territory in Serbia is attacked by water erosion, and wind erosion is a significant problem in the Vojvodina Province. The concentration of heavy metals and other potential pollutants in the soils of Serbia are not under the levels permitted by law.

Key words: soil degradation, soil erosion, heavy metals, surface mining, salinization.

INTRODUCTION

Soil, like air and water, is essential to support life on earth. Over 90% of all human food and livestock feed is produced on the land, in soils which vary in quality and extent. Of the earth's 13,000 million hectares of ice-free land surface, only 3% is covered with highly productive soils, 6% with moderately productive and 13% with slightly productive soils. The remaining 78% of land has limitations which normally prevent its soils from being used for cultivation; even grazing is limited. It is here, however, that most land and soil degradation occurs (Hurni, H., et al, 1996).

A distinction should be made between land degradation and soil degradation, as these terms are often incorrectly and interchangeably used. Land degradation includes degradation of soil, fauna and flora, water, (micro)-climate, and losses due to urban/industrial development, and is likely to have impact in entire ecoregions, such as in the many areas of the world affected by desertification. Land degradation is a much broader concept than soil degradation.

NATURAL FEATURES OF SERBIA

The Republic of Serbia, which occupies the central part of the Balkan Peninsula, has a total area of 88.361 km², and is characterised by different types of relief, from large lowlands in the north (Autonomous Province of Vojvodina) through hilly terrains and valleys towards the south, to mountainous districts in the west, south and east parts of the Republic.

The largest part of the territory of Serbia belongs to the temperate climate belt. Rainfall is one of the most important climatic elements. Depending on the atmospheric processes and the relief characteristics, rainfall in Serbia is irregularly distributed in time and space. The relief of Serbia offers favourable conditions to water erosion.

Land use is a social category and it has an essential significance in the occurrence, development and intensity of water and wind erosion. Table 1 shows that land use in Serbia enables the development of intensive processes of water and wind erosion.

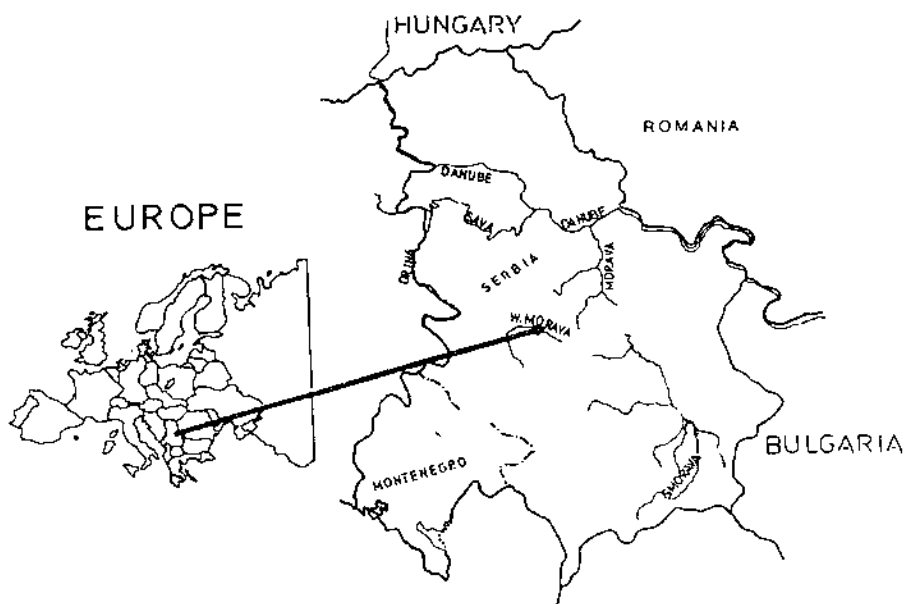


Fig 1. Study Area

According to the data quoted, it can be stated that considering the total agricultural surface area, i.e. within the limits of the quoted standard, in Serbia the surface area per capita is sufficient for a modest level of development only. The agricultural land in Serbia can be considered equal to 0.59 ha per capita.

Table 1. Land Use in Serbia

N ^o		Total area	Ploughed land and vineyard		Meadows, pastures and orchards		Forests		Other	
			km ²	%	km ²	%	km ²	%	km ²	%
1	Serbia	88.361,0	37.295,0	42,21	19.257,0	21,79	23.592,0	26,7	8.217,0	9,3

This data clearly indicate that Serbia is not so rich in agricultural land, and therefore degradation and destruction need to be prevented. Different forms of aggression upon the soil are present, from partial damage and different forms of pollution to total destruction and permanent disappearing. Human activities aimed at intensifying vegetation production through land utilization, though being apparently finalized to preserve or improve soil properties, frequently have the opposite effects, determining deterioration of the productive properties.

SOIL DEGRADATION IN SERBIA

Factors of soil degradation

The main factors of soil degradation in Serbia are:

1. Soil erosion and wind erosion;
2. Heavy metals and pesticides, and other chemical problems;
3. Salinization of soils;
4. Surface mining;
5. Construction of hydro-power plants and their reservoirs;
6. Urban and industrial expansion;
7. Flooding;
8. Water-logging;
9. Physical degradation (i.e. trampling and mechanical compaction);
10. Desertification.

Soil erosion by water and wind is present in many areas. Torrential furrows and ravines have been developing as consequence of growing corn and potatoes along steeply inclined plots. Deforestation and land reclamation have also intensified erosion processes.

Apart from natural factors, inadequate land use (anthropogenic factors), has been playing the main role in provoking soil erosion. This statement is proved by investigations carried in hilly-mountainous Juzna Morava River Watershed, which is representative of wider hilly-mountainous area of Serbia. With reference to anthropogenic factors, development of the erosion processes in the examined area can be divided into two periods: a first one up to mid 1950s, 1960s, i.e. up to the largest agrarian overpopulation, when the erosion processes acted in one sense; and another one after the mid 1950s, 1960s until now, when the erosion processes have been reversed.

In Serbia, processes of soil contamination and degradation are fairly intensive, and different soils have suffered various degrees of damage. With reference to soil contamination with heavy metals in the vicinity of industrial facilities, increases have been registered particularly in the amount of lead and zinc. Waste dumps are extremely detrimental for the soils as well for agricultural crops when contaminants are carried by wind. Extreme forms of soil degradation have been registered around power plants fuelled by coal, because of the emission of aerosols and gases laden with SO₂ and NO₃. When carried by wind, fly ashes from power plants damage both soil and plants. Fluor damages have been registered around aluminum plants. The expressed examples of soil degradation due to negative impact of the industry are the regions of Bor and **Trepča, as well as the municipalities of Priština, Kosovska Mitrovica, Obilić and Kosovo Polje**. At Kosovo, the soil in the vicinity of mines and industrial plants is being rapidly degraded in an uncontrolled manner by the dugouts, mining residues, ash, slag, heavy metals, waste waters and gases, and measures for protection and sanation and recultivation are generally lacking except for the smaller areas. Some municipalities are in a very difficult situation.

Irrigation practices caused salinization of surface soil layers and deterioration of physical and chemical soil properties in the irrigated areas (**Dragović, S., 1993**).

A particularly serious form of land damage has been caused by surface mining for various minerals and ores. Excavation of wide and deep craters produced moon-like landscapes in some locations (so-called industrial deserts). Another form of land damage resulted from depositing overburden from excavation sites over the fertile soil. When industrial dumps with fly ashes from power plants and red mud from aluminum plants are added, these forms of land damage are severe and also increase.

Another form of land damage resulted from the construction of hydro-power plants and their reservoirs which have irreversibly turned tracts of highly fertile soils into artificial lakes.

Urban and industrial expansions also contribute to reduction of agricultural land. Housing projects and industrial facilities are frequently erected on flat and highly fertile alluvial soils. In average, the productive surface areas (agricultural land) in Serbia are reduced annually by 117 km² (11,700 ha), with the greatest reductions in Vojvodina (74 km²), and the largest part in reduction of the productive surface areas belonging to the transformation of the better bonity classes (1 - 3), making the problem even more serious (**Kišgeci, J., 1993**).

Flooding and waterlogging of soils occur in the lowland along the rivers.

Introduction of an intensive agricultural production system which implies the use of heavy agricultural machines is another factor which has enhanced soil degradation (physical degradation-trampling and mechanical compaction), i.e., deterioration in physical and chemical soil properties. Another consequence is reduction in the humid content, which has reached the value of 50% in some regions, especially in the chernozem zone (Vojvodina Province).

In the last decade in Serbia (and especially in east Serbia and Vojvidina) the process of desertification occurs as a consequence of climate change (decreasing of annual values precipitation and increasing of air temperature).

Extensive measures have been introduced in Serbia with respect to soil protection. First of all, soil reclamation projects have already reclaimed several thousand hectares for agricultural production. Drainage and flood control are reinforced in lowland to reclaim considerable areas exposed to surface

and ground waters (pseudogleys and swampy soils). Attempts are made to reclaim erosion-endangered areas by important volume of erosion control works (forestation and landscape designing, i.e., by constructing terraces, torrent control and other) (Kostadinov, S., 1998).

Water Erosion and Sediment Transport in Serbia

Water erosion is the dominant type of erosion in upland regions of Serbia (about 75% of the total area of Serbia belongs to hilly-mountainous regions).

Water erosion occurs in the form of pluvial erosion on sloped lands and fluvial erosion in watercourses. Water erosion in Serbia may assume different intensities (Table 3). The commonly used classification of erosion (Gavrilović, S., 1972) includes 5 categories (from very weak to excessive). The **Erosion Map (prepared according Gavrilović's method)** presents the share of individual categories of water erosion.

Excessive erosion is most represented in the catchments of the river Južna Morava and Beli Drim (about 7% of total catchment area), and in smaller catchments, in the case of Pčinja (18%). Severe erosion occurs in the catchments of Pčinja (39%), Lepenac (26%) and Zapadna Morava (29%).

Erosion intensity was measured during a short period on erosion plots (runoff plots) at several localities in Serbia (Đorović, M., 1990). **Sediment transport produced as a consequence of soil erosion** was measured only in a seven experimental catchments (Kostadinov, S., 1995, 1996) in west and southeast Serbia.

Table 2 Distribution of Water Erosion Processes in Serbia

Category	Erosion Processes Intensity	SERBIA	
		km ²	%
I	Excessive Erosion	2,888.0	3.27
II	Intensive Erosion	9,138.0	10.34
III	Medium Erosion	19,386.0	21.94
IV	Weak Erosion	43,914.0	49.78
V	Very weak Erosion	13,035.0	14.75
Total		88,361.0	100

Source: Water Resources Management Basic Plan of Serbia, 1996

Table 3 Gross Erosion and Sediment Transport in Serbia

Republic	Gross erosion		Annual sediment transport	
	Total	Specific	Total	Specific
	m ³ ·yr ⁻¹	m ³ ·yr ⁻¹ ·km ⁻²	m ³ ·yr ⁻¹	m ³ ·yr ⁻¹ ·km ⁻²
Serbia	37,249,975	421.57	9,350,765	105.80

Source: Calculated by S.Gavrilović's method (1972)

Water erosion causes great damages, such as: soil loss, water loss, loss of nutrients, disturbance of runoff regime in the watersheds, catastrophic floods, reservoirs siltation etc. Soil erosion also causes very important damages to the environment, such as environmental degradation (on-site effects), mechanical pollution of water in the streams and reservoirs, chemical pollution of water by manures and fertilizers, chemical pollution by pesticides (off-site effects).

Wind Erosion

Wind erosion is a process dominant in the northern part of Serbia, i.e. in the Autonomous Province of Vojvodina, pedo-geographic region 1, (the region of sandy areas, Deliblato, Subotica-Horgoš) and in the right side of Danube river (the region of sandy area Ram Sands). Other lowland terrains are also exposed to occasional severe actions of wind, causing serious erosion.

Wind erosion causes great damages such as: soil loss and deterioration of the most fertile surface layer of the soil; covering of the most productive soils with poor-quality wind sediments; loss of seeds,

artificial fertilizers, and plant protecting agents. Hence, the measures to be adopted for reclaiming become more complex and more costly. In 1981, near the village Tavankut (Subotica-Horgoš Sands, northern part of province Vojvodina) a stormy northwest wind took off about 194 t/ha of sandy soil from a newly-established orchard in one day only (Letić, Lj. Et al 1995). The average annual intensity of wind erosion for Province Vojvodina, calculated by Pasak's method, is 1.82 t ha⁻¹yr⁻¹.

DISCUSSION

The scope of the problem, which should hopefully be solved in the near future, can be understood by considering the following elements:

- Serbia has a network of torrents distributed throughout the whole country. Regions where almost all rivers flow (and especially in the watersheds of the rivers Južna, Zapadna and Velika Morava), are crossed by a network of more than 12 thousand torrents. The consequence is that, in practice, 100% of the territory is attacked by different categories of water erosion. Actions aimed at controlling erosion have been so far insufficient, determining instead a further intensification and extension of erosion processes, worsening the water regime, and even other branches of economy, as well as the ecological future of next generations;
- Erosion also affects a high number of industrial facilities and settlements, even when they are far from the eroding area. Erosion, through its exponential factors - floods and droughts - reaches regions which are not connected with erosion processes. More than 500 settlements have been endangered by torrential floods, and even houses have been destroyed;
- Soil loss due to erosion in mountainous regions results from soil washing down the steep slopes to the streams, with deposition of sterile erosional sediment brought by the torrents in the valleys. By this way, soil loss caused by erosion of sloped land also affects the valleys. Consequently, erosion control is necessary not only for improving the water regime, but also for protecting the soil as the factor of food production;



Fig 2. Water erosion in the Južna Morava river watershed

- Erosion control and watershed management may offer significant solutions to current problems such as lack of water and water quality, which are related to the intensity of runoff, i.e. to the state of the soil and to the type of plant cover on the slopes;
- Although recently sheet erosion has decreased in the prevailing part of Serbia territory, this situation is only apparent and unstable, as it is not the result of active erosion control, but the result of social changes. People abandoned their arable land, which is economically unfavorable, because they were not able to achieve the result of minimizing erosion and maximizing at the same time plant production. That is why organizations for erosion control should be mobile, as

erosion may be the hidden enemy which can always surprise us, due to some natural phenomena or due to social changes.

If adequate measures for the control of erosion are not taken, the processes of water and wind erosion will be intensified, which will lead to:

- irreparable loss of the productive soil layer, resulting in serious shortages in food production;
- loss of soil fertility;
- deposition of sediment on arable soil, resulting from water and wind erosion;
- siltation of water storages by erosion sediment and consequently shorter periods of their exploitation;
- more serious environmental disturbances (landscape degradation, mechanical and chemical contamination of water in watercourses and storages);
- disturbed regime of runoff from watersheds and catastrophic torrential floods, destruction of settlements, industrial facilities, roads, and even human lives.

If the soil is not protected from pollution with heavy metals and pesticides, serious ecological problems will occur. Soils contaminated will have to be excluded from plant production, which will lead to additional reduction of food production.

CONCLUSIONS

Soil erosion (by water and wind) is the most serious factor of soil degradation in Serbia. The whole area of the country is affected by water erosion, and wind erosion occurs in Vojvodina. Control of soil erosion is the first priority for preventing soil degradation in Serbia.

It can be stated that concentration of heavy metals and other potential pollutants in the soils of Serbia are not under the levels permitted by law. Extreme forms of soil degradation have been registered around power plants fuelled by coal. The problem also exists in areas surrounding big factories.

Serious forms of soil (land) degradation have been caused by surface mining for various minerals and areas. These processes have taken place in Kolubara, Tamnava, Kostolac and Kosovo.

Agricultural land needs to be protected against irrational and inappropriate utilization and pollution by dangerous and harmful substances. Also, the land utilized for exploitation of the mineral raw materials needs to be revitalized and made feasible for agricultural production.

In order to utilize the agricultural soil as rationally as possible, it is also essential to reconstruct the old irrigation systems and to built new irrigation systems, and use irrigation to intensify the agricultural production, also changing the seeding structure.

REFERENCES

- Djorović, M., 1990. Experimental Study of Erosion and Crop Production on Bench Terraces on Sloping Land. In the book: Soil Erosion on Agricultural Land; edited by: J. Boardman, I.D.L. Foster, J.A. Dearing: "John Wiley and Sons; Chicester, New York, p.p. 531-536
- Dragović, S. 1993. Opasnost od zaslanjivanja zemljišta u sistemima za navodnjavanje u Vojvodini; U knjizi "Teški metali i pesticidi u zemljištu", Poljoprivredni fakultet i Institut za ratarstvo i povrtarstvo, Novi Sad, str. 269-290.
- Gavrilović, S. 1972. Inženjering o bujičnim tokovima i eroziji, Časopis «Izgradnja», specijalno izdanje, Beograd, p.p. 1-292
- Hurni, H., with the assistance of an international group of contributors 1996. Precious Earth – From Soil and Water Conservation to Sustainable Land Management. International Soil Conservation Organization (ISCO) and Centre for Development and Environment (CDE), Berne, p.p. 1-89.

- Kišgeci, J. 1993. **Legislative zemljišta Srbije; U knjizi "Teški metali i pesticidi u zemljištu", Poljoprivredni fakultet i Institut za ratarstvo i povrtarstvo, Novi Sad, str. 299-304.**
- Kostadinov, S. 1998. Soil and water conservation as a factor of nature protection in Yugoslavia; International Workshop on "Protection of natural resources in agriculture of Central and Eastern Europe", Kralupy nad Vltavou and Prague-Zbraslav, Czech Republic, 30 Nov. to 7 Dec. 1998, p.p. 24-27.
- Kostadinov,S., Topalović,M. 1995. Erosion Losses of Humus and Nutrients Depending on Land Use in the Watershed. Proceedings of Third International Symposium on Headwater Control. **"Sustainable Reconstruction on Highland and Headwater Regions".Oxford and IBH Publ. CO.PVT.LTD. New Delhi, Calcuta. p.p.279- 288.**
- Kostadinov,S.,Marković,S. 1996. Soil Erosion and Effects of Erosion Control Works in the Torrential Drainage Basins of Southeast Serbia. IAHS Publication no 236, Wallingford, p.p. 321-332.
- Kostadinov,S.,Marković,S., Topalović,M. 1997. Erosion Sediment as Water Pollutant in Streams and Reservoirs. "Chemistry and Industry" ,Scientific Information Journal. Union of Chemists in Bulgaria.Sofia. p.p. 10-14.
- Letić, Lj., Savić, N., Božinović, M. 1995. Wind erosion in Serbia; Proceedings of International Conference **"90 Years of Soil Erosion Control in Bulgaria", Sofia, p.p. 226-231.**
- Republika Srbija, 1996. Prostorni plan Republike Srbije, Beograd, str. 1-72.



WIND EROSION RESEARCHES AND MONITORING IN VOJVODINA

Ljubomir Letic¹, Radovan Savic², Miljan Veljic³

¹ Faculty of Forestry, Belgrade, Serbia

² Faculty of Agriculture, Novi Sad, Serbia, Email: rassa@polj.ns.ac.yu

³ Public Enterprise "Vojvodinasume", Petrovaradin, Serbia, Email: vsumezss@eunet.rs

Summary: The wind erosion process, appearing as a consequence of the application of intensive technologies in agriculture and global climatic changes, has already encompassed a significant part of Europe. The region of Vojvodina, as a part of the large Pannonian plain, is not exempt from this process. Destructive effects of wind erosion are most visible in agriculture. This paper focuses on effect of wind erosion on soils of light mechanical composition on the Subotica Sands and Deliblato Sands.

Keywords: wind erosion, soil degradation, soil loss

INTRODUCTION

Both natural and anthropogenic conditions favour occurrence of wind erosion in the territory of Vojvodina (northern part of Serbia). The continental climate of the Pannonian Plain is characterized by with frequent strong winds, attaining even rates of 40 m/s. Annual precipitation is sometimes even below 300 mm, with large temperature amplitudes. There is a markedly plain relief, with more than 70% of the area being plough fields which are at a time without any vegetation cover and which under conditions of intensified agricultural production may become very erodible. Forest areas are insufficient (~ 6.4%) and inappropriately located. The listed factors clearly indicate that the danger of wind erosion in Vojvodina, especially on sandy soil areas (The Subotica Sands and The Deliblato Sands), is potentially very high, and if the predicted climatic changes are going to occur, the situation may be even worsen (Savic, 1999; Letic et al., 2001; Savic & Letic, 2003)

Destructive effects of wind erosion in Vojvodina are particularly visible in agriculture. Due to wind erosion, soil - one of fundamental natural resources, becomes degraded. The wind carries out the finest humus particles, and also the nutritive and protective matter, and the just sown crop grains, pulls out and breaks young plants, denudes the roots of perennial plants, causes excessive evaporation and soil drying, and the blows of wind-borne particles damage green parts and fruit of the grown crops. In addition, wind sediments fill in the drainage and irrigation canals and water reservoirs. The loss of nutrients and moisture from the soil, repeated sowing, lower and non-uniform yields can also question the profitability of the agricultural production in the areas endangered by wind erosion, and especially in present times, when the intensive agricultural production is very expensive. On the other hand, attenuation of wind erosion processes can directly lead to lowering of the production costs, increasing probability of high yields and even under unfavourable climatic conditions (Letic & Savic, 2002; 2007)

MATERIALS AND METHODS

Wind erosion is essentially a very complex problem requiring that all its stages (initiation of movement, transportation, and deposition) should be taken into account by the study and quantification, i.e. all the relevant factors should to be considered. In 1980, on the Subotica Sands a special centre was founded to monitor wind erosion in soils of lighter composition. Investigations encompassed instrumental measurements of the intensity of wind erosion (rotation run-off sampler) and monitoring relevant climatic parameters and the state of the soil affected the wind action. Experimental station record quantity of Aeolian deposition, wind frequency and velocity, air and soil temperatures, air and soil humidity etc. These investigations have been carried out simultaneously at two measurement stations, one under the conditions of intensive agricultural production with no wind protection (location "A"), and the other in the forest protection belt (location

"B"), (Letic, 1989; Letic et al., 2001).

This paper presents results of research concerning effect of wind erosion intensity on soils of light mechanical composition on the Subotica and Deliblato Sands.

The Subotica Sands are located in the north part of the Vojvodina Plain, between the Danube and Tisza Rivers (average length 50 km and diameter 5-10 km, area 24,000 ha). It is a well-known orchard-grape vine region, with more than 33% of the total area under vineyards and orchards, 20% under forests and woodlands, and over 34% under grassland (Letic, 1989).

Permanent monitoring of the process of wind erosion in Deliblato Sands is performed since year 2006. Deliblato Sands covers south- eastern Vojvodina, averaging 35 km in length and 15 km in width, with a total area close to 35,000 ha. Majority of the region is forested (forests and forest culture 48.8% and forested regions that were affected by previous fire 4.9%), overgrown 88.8%. Exploration of erosion processes was conducted in 3 locations: 1) **Cvijićev vis**- erosion field unprotected from the wind, bear, permanently cultivated, light soils; 2) **Dragićev hat I** - erosion field protected from the wind, surrounded by the forest, permanently cultivated; 3) **Dragićev hat II** -erosion field in close vicinity to the previous field, with similar characteristics, however it is overgrown by grass cover. In all the three locations soil consists of greyish-yellow sand, as the most threatened type of soils, due to the fact that they represent the initial phase in f surface soil cover formation. Deflationmeters are used for quantifying wind erosion processes.

RESULTS AND DISCUSSION

SOIL LOSS ON THE SUBOTICA SANDS

A comparative method of stationary observation by wind-gage stations was applied in selected erosion plots, among which one, used for agriculture, were not protected (loc."A"), while the other (loc."B") was protected with forest planting. The obtained results suggest the existence of significant erosion processes outside the protective forest belt.

Different factors causing wind erosion, and simultaneous occurrence of unfavourable erosive events, resulted in the occurrence and development of erosion processes of various intensity. In the 1980-2000 periods, frequent variations in the wind erosion intensity and in some qualitative characteristics of the wind sediments were registered. The annual amounts of wind-borne sediments initiated in the Subotica Sands are in the range from 1.35 to 43.19 kg/m on the unprotected area, and from 0.10 to 0.59 kg/m on protected areas (Fig. 1.). In addition to the quantification and qualification of deflation processes in Subotica Sands, the degree of protection by the vegetal cover (shelterbelts) was evaluated, and it amounts to annual intensities 4 - 98 (on the average 20.7). The above readings show that intensity of wind erosion was reduced in the protected field.

Measured monthly intensity of wind erosion indicated the potential danger of moving large quantities of sediment at the sites without wind protection ($E_n=0.549$ kg/m). At the wind protected site, registered intensity of erosion process was considerably lower ($E_n=0.029$ kg/m), Fig.2. The ratio between these values is an indication of the protective effect produced by the forested areas. It can be concluded that, under extraordinary circumstances, as much as 500 times more of erosion material may be moved from the arable non-protected areas (18 times on average) during a month. During only one month, or even during shorter erosion process, over 70% of the total annual quantity of deposited sediment may enter in motion.

The average monthly distribution indicates periods during which the danger of erosion process development is increased. Two characteristic periods are rather obvious: spring (March, April) and early autumn (September), during which considerably higher average monthly intensities of wind erosion compared to the other months (Fig. 3.).

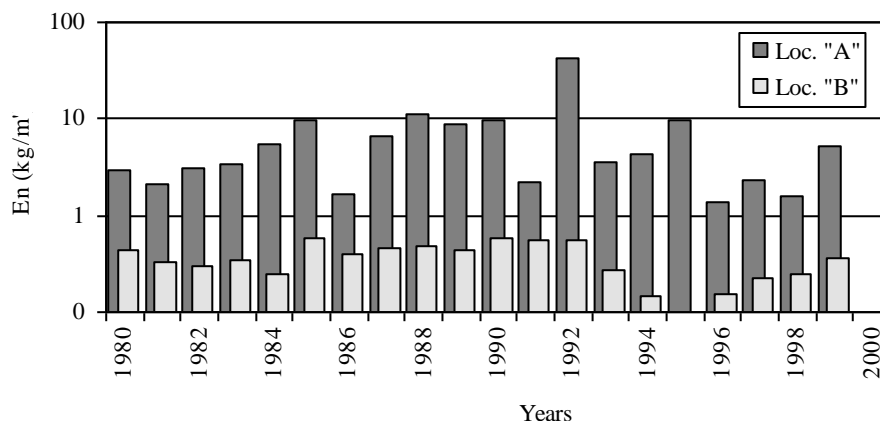


Fig. 1. Annual wind erosion intensities on the Subotica Sands, E_n (kg/m²):
 "A" – Ploughed field with no wind protection; "B" – area in the protective forest belt

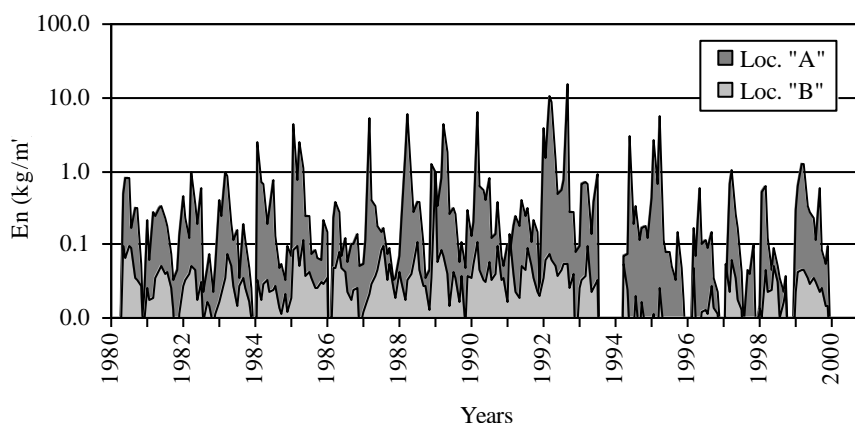


Fig. 2. Monthly wind erosion intensities on the Subotica Sands, E_n (kg/m²):
 "A" – Ploughed field with no wind protection; "B" – area in the protective forest belt

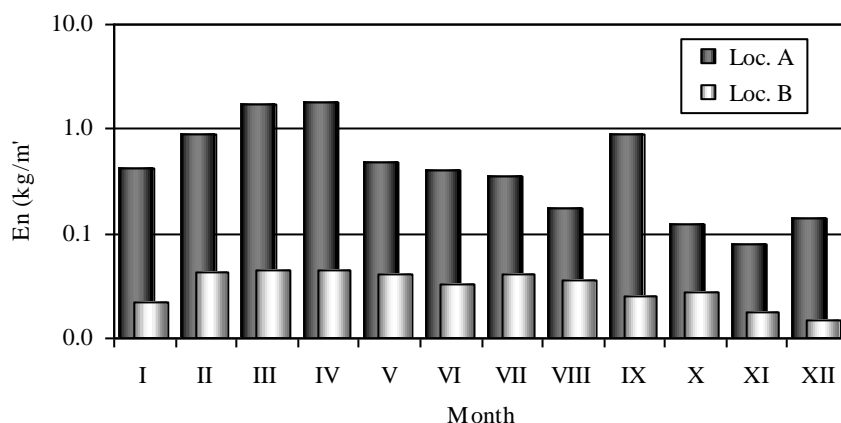


Fig. 3. Average monthly wind erosion intensities on the Subotica Sands, E_n (kg/m²):
 "A" – Ploughed field with no wind protection; "B" – area in the protective forest belt

In addition to quantification of deflation processes in the researched area, analyses of quality were performed, i.e. physical and chemical properties of the Aeolian deposition were defined and compared to the same characteristics of the residual, surrounding soil. The following nutrients, which are removed from the soil complex of the Subotica Sands, were considered: humus, total nitrogen, readily available phosphorus and potassium. Chemical analyses of sediments indicated its increased load of nutritive matter compared to the residual soil from which the sediment was originated: humus up to 9 times, nitrogen up to 10 times, phosphorus up to 8 times, and potassium up to 4 times, and even more.

SOIL LOSS ON THE DELIBLATO SANDS

Quantities of measured eroded sediments are showing that the most intense processes of wind erosion occurred in Cvijićev vis location, where these processes resulted to be 4 times larger than those measured in Dragićevo hat I location, and 32 times larger than values measured at the location Dragićevo hat II – which is protected by wind with grass cover.

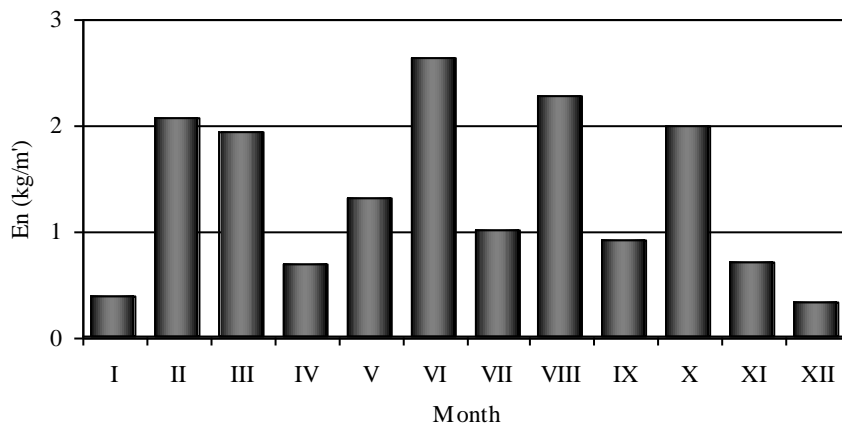


Fig. 4. Average monthly wind erosion intensities on Cvijićev vis location

Monthly intensities of wind erosion during a period of monitoring on Cvijićev vis location were ranging from 0.34 kg/m in December to 2.65 kg/m in June, with an average value of 1.36 kg/m per month (Fig. 4). Preliminary results of wind erosion monitoring on Deliblato Sands are showing that there are higher potential intensities of wind erosion processes compared to wind erosion processes in Subotica sands, where monthly intensity values from 0.08 kg/m in November to 1.82 kg/m in April were measured.

With reference to mechanical composition of wind sediments, high concentration of fine sands, up to 91%, has been detected, and this is a much higher concentration compared to Subotica location, where a maximum value of 79% has been detected. This result shows that that wind erodibility potential in the sands in Deliblato location is very high, particularly in absence grass and forest cover.

CONCLUSIONS

In natural and anthropogenic conditions in the territory of Vojvodina deflation processes represent important factor of soil destruction, and have a negative effect on other elements of the environment like water and air. Comparative research on the protected and unprotected erosion fields and presented results pointed out the significant degree of the vegetative cover protective effect.

In the analysed period, frequent variations in the wind erosion intensity and in some qualitative characteristics of the wind sediments were registered. The annual amount of wind-borne sediments initiated in the Subotica Sands is in the range from 1.35 to 43.19 kg/m on the unprotected area, and from 0.10 to 0.59 kg/m on protected areas. The degree of protection by the vegetal cover was evaluated, and it amounts to annual intensities 4 - 98 (on the average 20.7).

On the Deliblato Sands - Cvijićev vis location (1.29 kg/m), more intense processes of wind erosion were identified, which are 4 times larger compared to values measured in Dragićevo hat I location (0.32 kg/m), and 32 times larger than values measured in location Dragićevo hat II (0.04 kg/m) – which is protected by wind with grass cover.

The processes of accelerated wind erosion are most frequent because of anthropogenic factors, inappropriate use of soil, vegetation destruction, etc. Modern measures of wind erosion control must be complex, all-inclusive, continuous, and systematic. It is important to bear in mind the fact that there is no absolute

protection from wind erosion, that is, there is no possibility of complete elimination of wind erosion processes, and the only possibility is to reduce them to a rationally acceptable level. It would be highly desirable to establish a network of measuring stations aimed at monitoring wind erosion in Vojvodina under different natural conditions (microclimate, soil, etc.), as well as under different crops. By this way, it would be possible to check the accuracy of the applied empirical methods and to achieve a more reliable estimation of the erodibility of particular types of soils, the protecting effect of the crop cover in particular stages of crop development, the effects of different modes of soil cultivation, and of soil moisture. It should be especially pointed out the importance of establishing the amount, characteristics, and composition of the wind erosion sediments, as this is a crucial factor of degradation in the environment.

REFERENCES

- Letic, Lj., (1989): Research of wind intensity in the region of Subotica-Horgos sands, Doctoral dissertation, Faculty of Forestry, p. 307, Belgrade.
- Letic, Lj., Savic, R., Bozinovic, M. (2001): Moving sand, monograph, p. 164, Subotica.
- Letic, Lj., Savic, R. (2002): Wind Erosion in Vojvodina, The fifth international conference on Aeolian research, ICAR-5, pp.164-167, Lubbock, Texas, USA.
- Letic, Lj., Savic, R. (2007): Soil degradation by wind erosion in Vojvodina", International Conference: Erosion and torrent control as a factor in sustainable river basin management, CD, Topic A: Degradation processes, p. 1-6, Belgrade,
- Savic, R. (1999): Hazards from wind erosion of soil in Vojvodina, Doctoral dissertation, p. 170, Faculty of Agriculture, Novi Sad.
- Savić R., Letić Lj. (2003): Wind erosion on light soils in Voivodina, Journal: Annals of the Faculty of Engineering Hunedoara, Tome I, Fascicule 2, pp. 5-10, Hunedoara, Romania.**



NECESSITY FOR SUSTAINABLE UTILISATION OF SOIL AND WATER RESOURCES

Miodrag Zlatic

President of WASWC, Professor of the Faculty of Forestry, Belgrade University

Summary: Land degradation is the global problem from the beginning of mankind. For some decades, the talk has been that our society is driving our planet along a collision course with environmental crisis. Our economies are consuming much more than the earth can provide and our profligate life-style is laying waste to our lands. Our society is using up the capital of the earth when it should be living from the interest. Our current way of life is not sustainable. Equally, our society recognizes that it has an obligation to pass to future generations a world that is as productive and full of potential as the one it inherited (Jansky, Haigh and Prasad, 2005). An **African proverb that best explains sustainability is: „The earth is not ours, it is treasure we hold in trust for our children and their children“**. Sustainable utilization of land resources is presented in this paper through the modeling of SLM and its natural and economic effects, as well as through the public participation in its implementing in practice. A conceptual model of production in hilly regions has been developed and presented on the example of the hilly Topcidarska river watershed. Possibilities for the improvements of the offered production model are presented. According to the long-term effects and analysis, one can conclude that it is cost-effective to invest in these purposes. A participatory approach is necessary to implement such programmes, how it is explained in **the "Grdelicka Gorge" – case study**.

Keywords: land use, degradation, erosion, SWC (soil and water conservation), sustainability

INTRODUCTION

As worldwide, the major factor provoking soil erosion in Serbia is the anthropogenic factor. Development of erosion processes occurred into two different periods, one going until 1950s, and a second one going from the mid 1950s to the present day. The first period was characterized by the highest agrarian pressure and accelerated erosion. The second period was characterized by population migration, large extent of erosion control works, changes in the structure of agricultural production and consequent decline in erosion intensity. The high agrarian pressure in hilly-mountainous regions was primarily reduced by migrations (Zlatic, M. 1998). As younger household members migrated, arable fields were left uncultivated, invaded by weeds, and converted into pastures, thus contributing to diminishing erosion. However, this process cannot be considered development. Rehabilitation of degraded regions should be determined by people remaining in the area and being able to have decent livelihoods. Participation of all stakeholders in sustainable land management and decision making can make it possible.

Sustainable utilization of land resources is presented here by two examples: (1) modelling of SLM in Topcidarska river watershed and (2) public participation in sustainable management of land resources of Grdelicka Gorge.

The Topcidarska River watershed is characteristic for incidence of all the erosion phenomena in the agricultural areas of the Rakovica and Vozdovac communities, which constitute the part of the hilly region of the wider Belgrade area. On the basis of the detailed terrain reconnaissance it has been established that the main cause of the intensive erosion processes in this region is the inadequate land use. Agricultural land occupies 2484.23 ha. On the arable land, due to small surface areas of the land pieces and to the impossibility to turn the machinery around, tillage is mainly performed along the slopes. According to the USLE method, the average soil losses from the agricultural surfaces of this morphological unit is $23.84 \text{ t} \cdot \text{ha}^{-1}$. Due to these circumstances, the yield and income from the agricultural products are not adequate to the potential values that could be achieved according to the natural and economic conditions of this region.

MATERIALS AND METHODS

Method of natural effects of planned model

On the basis of terrain reconnaissance at 61 sample plots located in the agricultural soil of Topcidarska river watershed, soil losses have been estimated according to USLE erosion equation for the

current soil utilization, and also making predictions for the future based upon the soil management for sustainability principles (SLM).

Production models

The basic production model was developed from the aspect of SLM, the needs of the population in this area and potential economic effects. Production is primarily planned in a quantitative sense, i.e., the relations are designed between the groups within arable farming (erosion control crop rotations) and orchard production (classical orchards, orchards with self terracing and orchards with classical terraces), as well as pasture and forest areas. In the qualitative sense, the lines of production, the lines of production as per crop species are designed. Crops rotation includes cereals like wheat and oats, root crops (corn, soya beans and sunflower) and grasses. Orchard species include apple, pear, peach, apricot, cherry, sour cherry, plum, raspberry, blackberry and walnut. Improvements of the basic production model were performed by considering two variants: I variant – production of honey as the chief product, and wax, propolis and flower powder as by products (model II); variant II – production of royal jelly as the chief product without by-products (model III). The production of honey within the frames of the existing production can be organized as an additional activity in agricultural areas (sunflower production line), in orchards (apple, pear, cherry, sour cherry, apricot), in forest cultures (Black locust and Austrian pine) as well as in meadows.

Methods of Assessment of Economic Efficiency

Assessment of the long term effects of the planned model has been performed in terms of the Internal Rate of Return (IRR), Pay Back Period (PBP), Benefit – Cost Ratio (B/C) and Net Present Value (NPV). A period of 15 years has been chosen for the assessment of the economic efficiency according to the average production lifetime of stone-fruit orchard species.

RESULTS

MODELING SUSTAINABLE PRODUCTION

Natural effects of modelling sustainable production

The average soil losses from the agricultural surfaces of Topcidarska River watershed with the present land use, according to the USLE method, amounts to $23.84 \text{ t} \cdot \text{ha}^{-1}$. The sediment, as a product of the erosion processes, carries with it harmful substances both of organic and inorganic origin, and this also harmfully affects the environment. Taking into consideration the evident previous tillage down the slope, which causes **soil loss of $23.84 \text{ t} \cdot \text{ha}^{-1}$** , by the proposed model **of production the value of "C" (factor of land use) and "P"** (factor of erosion control) in the USLE equation will be reduced by about 8 times. Thereby, decreasing the soil losses below the limits of tolerance, it would assume an average value of $3.21 \text{ t} \cdot \text{ha}^{-1}$ for the whole watershed (Fig. 1).

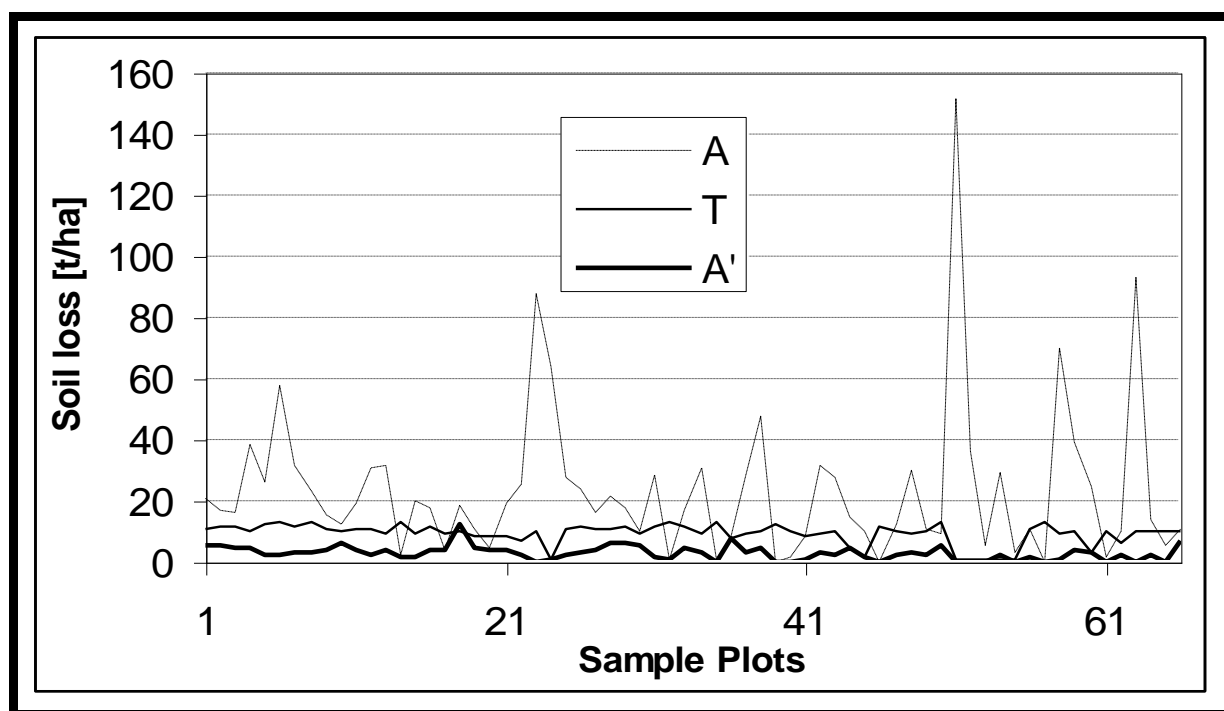


Fig. 1 Soil loss on the sample plots of Topciderska River watershed

Legend: A – Soil loss according to present land use ($t \cdot ha^{-1}$)
 T – Tolerant soil loss ($t \cdot ha^{-1}$)
 A' – Soil loss according to proposed model of production ($t \cdot ha^{-1}$)

Economic effects of the planned and improved models Internal Rate of Return (IRR)

Cost efficiency of the investments is calculated on the basis of the amount of the discount rate, where the present value of all inputs is equal to the present value of all outputs in the same statement of the accounts. It can be seen that the IRR amounts to 17.58 % for the planned production and to 19.30 for the improved production – variant I with honey as chief product, and 25.46 for the improved production – variant II with royal jelly as the chief product (Table 1). By comparing the calculated IRR with the real interest rate, which amounts to 12 % for Eastern European countries according to the International Bank for Development, one can conclude that the investment in soil conservation and in the proposed production variants is cost effective.

Pay Back Period (PBP)

PBP shows the period in which invested capital can be returned. The PBP for the planned production model is 10 years (model I), and for the improved model with honey as chief product is 9.2 years (model II). The improved production model with royal jelly as a chief product gives a satisfactory efficiency of PBP of 7 years (model III). As the credit return period for the majority of Serbian banks is 10 years, the method for the I model has to be tested by the sensitivity analysis of PBP. Model II and III give satisfactory efficiency (Table 1).

Benefit Cost Ratio (B/C)

This parameter represents the ratio of the total annual benefit and the total annual costs discounted to the initial instant at a discount rate of 12 %. One can see that B/C is 1.17 for the planned production of the model I, 1.20 for the model II and 1.30 for the model III. Since the value of this parameter is higher than 1, it is cost –effective to invest into any of the models suggested (Table 1).

Net Present Value (NPV)

This parameter represents the sum of total annual benefits discounted to the initial instant, at the discount rate of 12 %. It can be seen that this parameter amounts to 2.790 million EUR for the model I, 3.617 million EUR for the model II and 6.408 million EUR for the model III. Since NPV is well above 0, one can conclude that it is cost effective to invest in the designed erosion control works and the subsequent production models in this area. According to the calculated economic efficiency parameters, risk and uncertainty of investment assessments and their unmeasurable effects, it can be concluded that in the Topciderska River watershed the investments in soil management for sustainability are cost effective and beneficial for environmental conservation. The offered improvements of the production by introduction of the bee-hiving have considerably increased the economic efficiency, and simultaneously are very acceptable and adaptable for the small farmers, which is the additional reason for people to remain and survive in these areas.

Table 1. Parameters of economic efficiency

Model	IRR (%)	PBP (years)	B/C	NPV (mil. EUR)
Model I	17.58	10.0	1.17	2.790
Model II	19.30	9.2	1.20	3.617
Model III	25.45	7.0	1.36	6.408

CASE STUDY "GRDELICKA KLISURA (GORGE) – PUBLIC PARTICIPATION IN THE SUSTAINABLE MANAGEMENT OF LAND RESOURCES"

Process of public participation is presented through the case study of the non Governmental Organization "Center for Ecology and Sustainable Development", who has undertaken the project: "Grdelica's Gorge 2000 – Public Participation in Decision Making of Sustainable Land Resources Management", financed by REC - Regional Environment Center for Central and East Europe (Zlatic, M. et al. 2001). As consequence of natural conditions and inadequate land management, in mid fifties, the gorge Grdelička Klisura was one of the regions most endangered by erosion processes in Europe, and consequences of erosion led the population to misery and migration from this region. Today, elderly people households prevail in the villages of this upland region, with the alarming tendency of their extinction. Extensive areas remain uncultivated, so there is no production and the society has no benefit from this land, only the damage both in situ and downstream. The interest of this region should be to activate the appropriate plant production which will, under erosion control measures, reduce soil loss to tolerant limits. In this way, the soil as one of the most important natural resources will be conserved and it will also enable long-term natural and economic effects.

Our Project includes the activities which aim at the sustainable land management of Grdelička Klisura carried out with public participation in decision-making, i.e. participation of local population, production organizations, as well as the representatives of the authorities (Fig.1). This is achieved through direct discussions, advising, dissemination of information through public media, questionnaires and tribune discussion. In this way we have raised the awareness of all the representatives of the public who participate in decision-making on the sustainable use of natural resources, in this case land resources. The product of the project is the decision of target groups which represent the public of the selected village Grdelica to organize grape growing and fruit growing at the locality of "Grdelica Rid". The above was agreed by consensus of the population of this village and the Farming Co-operative Grdelica, under the definite responsibilities. The responsibilities referring to local population are the land lease, regular tillage, harvesting and selling the crop to the Farm Co-operative, whereas the Farm Co-operative should carry out the site preparation, construct the terraces, provide the planting stock, provide interculture, protection, fertilisation and guarantee the purchase of the crop.

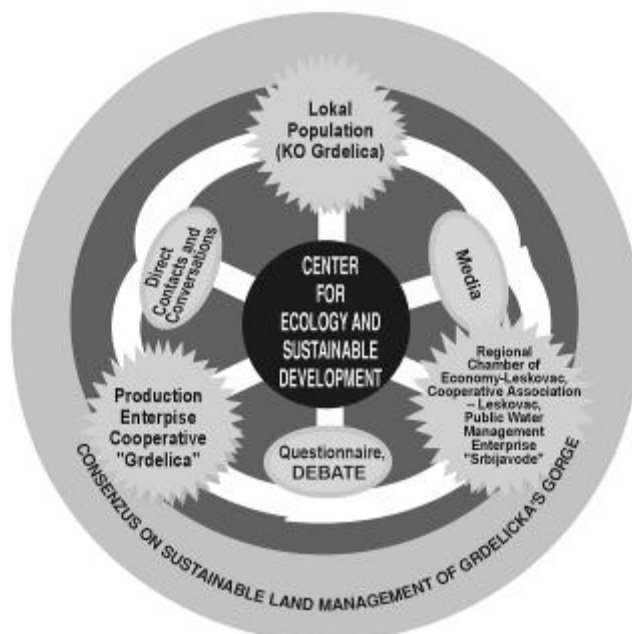


Fig. 2: Process of public participation

In the Regional Chamber of the Economy, the public debate discussion on this project was convened on February 2001. Along with the representatives of the Chamber of the Economy and the Centre for Ecology and Sustainable Development, the representatives of Water Management Enterprise "Srbijavode" took part in the debate, together with the representatives of the Co-operative Association of Leskovac Region, Co-operative Farm "Grdelica", and Local Community of the village Grdelica. The Project was accepted by consensus, which confirmed the significance of the public participation in decision-making on the sustainable management of land resources. Its influence is presented in Fig. 3.

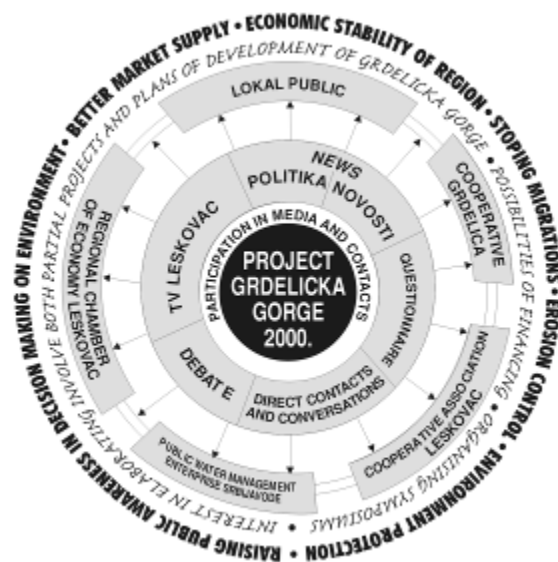


Fig. 3: Project influence

DISCUSSION

Further development of the hilly-mountainous regions must be based upon people remaining and surviving there. This could be possible applying the principles of the sustainable land use and profitability. A conceptual model of production in hilly regions has been developed and presented on the example of the hilly Topciderska River watershed. Possibilities are given for the improvements of the offered production model. According to the long-term effects and analysis of risk and uncertainty, one can conclude that it is cost-effective to invest in these purposes. The parts of this model can be seen occasionally in the great part of hilly mountainous regions in Serbia. The main issue is the implementation of this and similar projects in

the practice. This could be achieved through the public participation, whose significance has been appreciated after the Arhus Convention was adopted in 1998.

Strategies and Intended Action

Strategies and intended action have World's view in Ecosystem approach and European view in new research concepts in soil and water conservation, as it is DPSIR approach and Soil Thematic Strategy.

Ecosystem approach for land use management and soil conservation

"An ecosystem is a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit. An ecosystems can refer to any functioning unit at any scale: it could be a grain of soil, a forest, a biome or the entire biosphere. The Ecosystem Approach relates to relevant levels of biological organization, which encompass the essential structure, processes, functions and interactions among organisms and their environments. It recognizes that humans, with their cultural diversity, are an integral component of many ecosystems" (UNEP, 2000). The ecosystem approach requires holistic adaptive management to deal with the complex and dynamic nature of ecosystems and the complete knowledge or understanding of their functioning. It can integrate other management and conservation approaches and other methodologies to deal with complex situations. There is no single way to implement the ecosystem approach, as it depends on local, provincial, national, regional or global conditions. The application of it should be adapted to specific situations and frame conditions (Fig. 4).

Approach for analyzing the current situation

In order to bridge between theoretical knowledge and implementation of operational tools in SWC, the use of DPSIR approach (Blum, 2007) is proposed (Fig. 5). This distinguishes between Driving Forces (D), which develop Pressures (P), resulting in a State (S), which creates Impacts (I) and for which Responses are needed. A Driving Force (D) can be a demand for more space for industrial production, accommodation, transport facilities, sports and recreation facilities, duming of refuse and others. The pressure P, deriving from this demand, is urbanization in a broad sense, which means construction of new industrial premises, houses and transport infrastructure. The State (S) created through this pressure is sealed soils which means considerable losses of agricultural and forest land. The direct Impact (I) causes less agricultural land and forest biomass production, less rainwater infiltration, less biodiversity and problems with contamination, compaction, decline in soil biodiversity, decline in soil organic matter, salinization, erosion and floods and landslides.

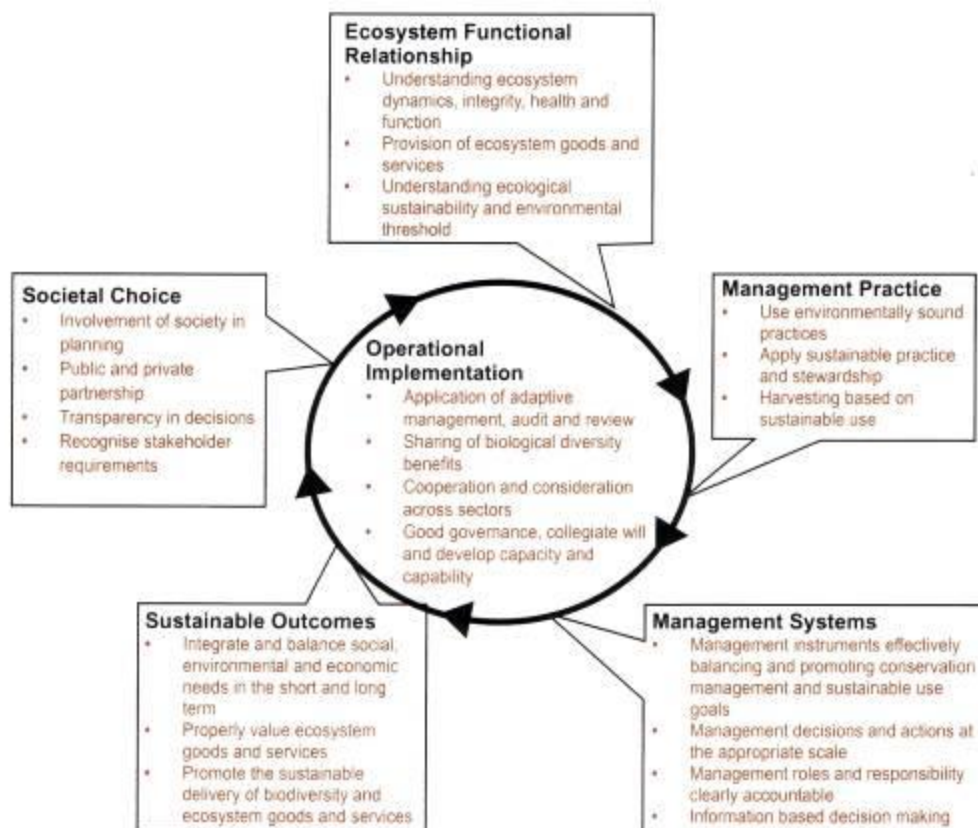


Figure 4. Ecosystem Approach

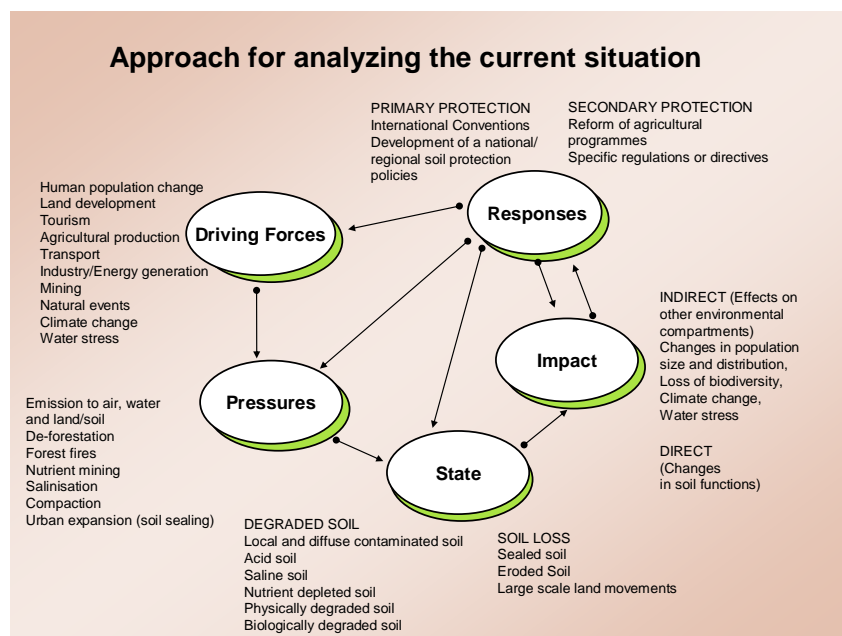


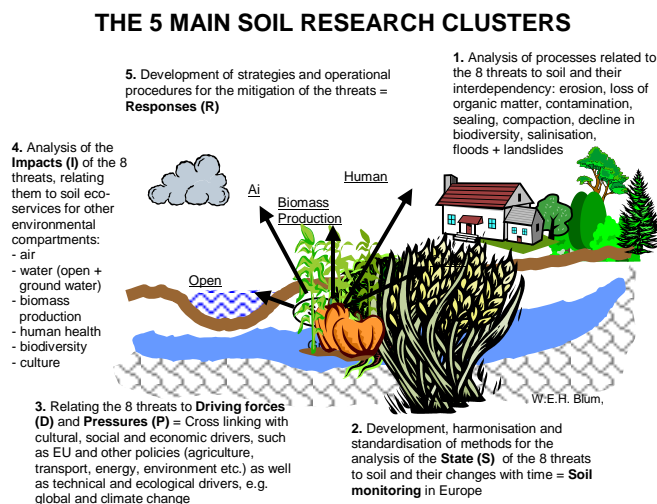
Figure 5. The DPSIR approach applied to soil

The responses (R) should be directed at the driving forces (D) through satisfying the demand for new urban structures instead of sealing new land (e.g. by recycling brown fields i. e. former industrial sites). Responses (R) can include social and economic measures, incentives or legal institutions in order to reduce urban sprawl. Based on this approach new research concepts were developed (Blum et al, 2007).

The five research clusters are shown in more details in Fig. 6, from which it appears clear that it is necessary to analyse the process related to the eight treats to the soil and their inter-dependency; to

develop harmonized and standardized methods for the analysis of the state of the eight threats to soil and their changes over time (soil monitoring). Based on that, the eight threats can be related to the driving forces and pressures, cross-linking them with cultural, social and economic drivers, such as EU, national and other policies.

Fig.6



Outlook and Conclusions

1. A holistic Soil Thematic Strategy provides a framework for the sustainable use of soil resources and environmental conservation.
2. The necessary methodological approaches for achieving these goals are:
 - The DPSIR approach, with which it is possible to understand and to manage complex ecological systems.
 - New available research concepts for the definition of indicators for soil quality, based on interdisciplinary and multidisciplinary approaches joining together technical, ecological, cultural, social and economics sciences.
 - Indicators based on this approach can represent a bridge between science and technology and stakeholders, decision making and politics, thus sharing knowledge between those who have it and those who need it.

REFERENCES

- Blum, W. 2007. Policies for Environmental Conservation in a Global Society, 5th International Congress of the European Society for Soil Conservation, Book of Abstracts, Palermo. pp 463-464
- Jansky, L., Haigh, M. and Prasad, H. 2005 (editors). Sustainable Management of Headwater Resources – Research from Africa and India. United Nations University Press. Tokyo. New York. Paris: 264-288.
- Singh, R. Y. 2005. Sustainable management of headwater resources: Interface drainage analysis of a water. Published in the book: Sustainable Management of Headwater Resources – Research from Africa and India. United Nations University Press. Tokyo. New York. Paris:87-105.
- Zlatic, M. and Dragovic, N. 1998. Demographic-Economic Aspects of Erosion Processes and Sustainable Soil Management in Hilly–Mountainous Regions, Serbia. **Proceedings of Headwater '98, the Fourth International Conference on Headwater Control, Merano-Italy**; Editors: Martin J. Haigh, Josef Krecek, G. S. Rajwar, Mariane P. Kilmartin; A.A. Balkema/Rotterdam/Brookfield/: 391-398.
- Zlatic, M., Kostadinov, S., Dragovic, N. et al. 2001. Grdelicka Gorge 2000 – Public Participation in Sustainable Soil Management (**Project financed by REC**); NGO "Centre for Ecology and Sustainable Development; Belgrade
- UNEP, 2000. Decisions adopted by the Conference of the Parties to the Convention on Biological Diversity at its Fifth Meeting, Nairobi, Decision V/6. pp. 15 - 26

SALT-AFFECTED SOILS IN HUNGARY

Tibor Tóth

Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences
(RISSAC), Budapest, **Herman O. út 15. 1022 Hungary**
E-mail: tibor@rissac.hu

Summary: Approximately 13 percent of Hungary is considered to be salt-affected, and with this large extent Hungary is unique in Europe. There are large areas of naturally saline and sodic soils, but also secondary salinization is known to occur.

Due to the geological and hydrological conditions, the country shows the most characteristic features of natural continental (not marine) salinization, sodification and alkalinization. Since the most important direct source of soil salinization is the shallow groundwater level below the lowland surface, there is a chance of irrigation-related salinization in two dominant situations: when the abundant use of river waters causes waterlogging and rise of saline groundwater (salinization from below); and when typically saline tubewell-waters are used for irrigation (salinization from above).

Spatial assessment of salt-affected areas began with the systematic mapping of salt-affected areas. There is a series of ten maps describing different aspects (salt-affected soil types, vegetation types, salt-efflorescences) of the salinity-status nation-wide from 1897 onward, with the latest survey which finished last year.

Besides the national scale of 1:500 000, soil salinity is also mapped at the scale of 1:100,000 on the "AGROTOPO" map sheets and 1:25,000 in the „Kreybig"-practical soil information (spatial vector data for maps and database for profiles and borings) systems. Although the two systems are digitally available, the information collected at the scale of 1:10,000 is available only for 2/3 of the country and is not digitised.

Traditionally, the study of salt-affected soils (SAS) is one of the most popular topics among Hungarian soil scientists. The origin, properties and reclamation of these soils (in Hungarian "szik") were investigated thoroughly during the last two centuries. A full list of the 22 monographs on salt-affected soils is reported by Tóth and Szendrei, 2006. Mapping of these soils started in 1897, mapping at the scale of 1:25,000 was finished by the 1950-es, and their last assessment, including now areas covered with native halotolerant vegetation, was carried out in the years 2003-6 (Bölöni et al., 2003).

ENVIRONMENTAL CONDITIONS IN HUNGARY

About one third of the soils on the Great Hungarian Plain (N 46-48.5⁰ and E 19-22.5⁰) is affected by salinity/sodicity, mainly by sodification, one third of the territory is covered by potential SAS, and one third does not have such soils. Potential SAS are defined as soils which are not salt-affected at present, but which could become considerably saline or sodic as a consequence of irrigation (Szabolcs, 1974). The territorial segregation of some types of SAS is evident (Fig 1). Soil types Solonchak and Solonchak-Solonetz are concentrated mainly in the Danube-Tisza Interfluve; types "Meadow Solonetz" and "Deep Mollic Solonetz"¹ are more typical in the Tisza Plain.

METEOROLOGICAL CONDITIONS

The Great Hungarian Plain is the hottest and driest region of the Carpathian Basin, which is otherwise characterized by temperate climate. Table 1 reports data describing annual averages and dynamism in the central region, where SAS are most common. The area of Hungarian SAS is located at an elevation of 80-90 m above sea level, under temperate characteristic of continental climate, with 10 °C mean annual temperature of, (-2 °C in January, +21 °C in July), 527 mm average annual precipitation (June is the most rainy month with 71 mm, March has the least precipitation with 28 mm), and 900 mm mean annual pan evaporation.

¹ In this report the term "Meadow Solonetz Turning into Stepp Formation" of Szabolcs, 1966 and Szabolcs, 1989 p 245 has been replaced by the term "Deep Mollic Solonetz" for reasons of clarity.

Table 1. Average meteorological parameters in the middle of the Great Hungarian Plain

Parameter (monthly)	1	2	3	4	5	6	7	8	9	10	11	12	Year
Precipitation (mm)	30	30	28	41	51	71	53	50	34	33	46	46	527
Potential Evaporation	12	19	40	78	112	136	156	144	106	58	25	14	900
Drought Index	0.40	0.63	1.43	1.90	2.20	1.92	2.94	2.88	3.12	1.64	0.54	0.30	1.71
Actual evap (mm)	11	15	27	63	102	91	76	58	35	21	16	12	527
Air temp (°C)	1.8	0.5	5.2	10.9	16.0	19.7	21.3	20.5	16.4	10.7	5.3	0.6	10.0

HYDROLOGICAL CONDITIONS

The Great Hungarian Plain is a basin filled with sediments deposited by rivers and wind. Therefore, the position of surface waters had an important impact on soil formation. These rivers, as typical lowland rivers, affected a vast territory by the periodic floods, creating huge marshlands. According to their origin, sediments deposited from the rivers differ much and the base materials of soil formation reflect these differences.

In the formation of salt affected soils a decisive role is played by saline groundwater, so the different types of SASs in the Hungarian soil classification system are closely related to distinct groundwater table depths. There are regional and local differences in the composition and concentration of groundwater that resulted in the wide variety of salt-affected soils.

SOIL CONDITIONS

According to the general Hungarian classification of soils, there are soils of the Atlantic Region (Brown Forest soils) in the hilly marginal regions of the plain and there are soils of the Steppe Region (Chernozems) in the inner plateaus of the plain. Important "azonal" soils are the salt-affected soils and Meadow soils. These soils, together with the "intrazonal" Alluvial soils, form a catena. As the parent material between the Danube and Tisza^{Hungarian} (=Theiß^{German} or Tisa^{Slovakian&Ukrainian}) Rivers is rich in calcium-carbonate, the Solonchak and Solonchak-Solonetz soils developed on the alluvial sandy soils are classified as "Calcareous Sodic soils", whereas the more or less leached Solonetz-like soils that were developing on the more acidic sediments of the Tisza River (loamy and clayey parent material) are frequently referred to as "Non Calcareous Sodic soils". The latter are characterized by higher clay-content and by unfavourable hydrophysical properties, high ESP (Exchangeable Sodium Percentage) and high pH in the columnar B horizon and, as a rule, low salt content. The unfavourable properties that limit the fertility of these soils are the consequence of the high clay content, high ESP, high pH and the resulting moisture regime. The climatic conditions, e. g. the unequal distribution of the precipitation, the high aridity index and the high fluctuating saline groundwater require a complex approach for improvement of these soils.

GROUNDWATER CONDITIONS

The Great Hungarian Plain consists of a variable layered and textured deep aquifer where the groundwater table varies between 0.5 - 4.0 meter below surface, with an average fluctuation of 0.5 -2.0 m. The shallow water table often causes waterlogging on the lower parts of the fields. Surface waterlogging appears also on the low-lying, low permeability plots at the end of winter, after snowmelt and/or during high-precipitation periods. The high salt content of the groundwater and its high Na⁺/(Ca⁺⁺ Mg⁺⁺) ratio often result in salinization and alkalinization of the soils.

THE FORMATION OF THE SAS OF HUNGARY

At the beginning of the Miocene geological Era [23 to 5.3 million years before present] between the ancient "Carpathian" and "Dinaric" Mountains a vast gulf of the "Tethys" ancient sea flowed in to create the "Parathethys". This sea gulf later became detached from the Tethys and – known as the "Sarmathian" or

"Pannonic" Sea – by the end of the Pliocene Era [5.3 million to 1.8 million years before present] has been filled up with several hundred meter thick alluvial sediment. During the Pleistocene Era [1.8 million to 11,550 years before present] this process continued and loess formation took also place on the previously deposited alluvial sand. In some areas the sand was blown into dunes.

On the parent materials formed during the Pleistocene Era the influence of shallow fluctuating, saline-sodic groundwaters, as well as the permanent or temporary waterlogging created the conditions of SAS formation. Sodium ions, being considered as the most important factors, either dissolved from the Tertiary Era [65 million to 1.8 million years before present] deposits into the groundwater (supported by data of Mádliné et al., 2005), or concentrated during consecutive drying and wetting of infiltrated water (as argued by Bakacsi and Kuti, 1998). Szöőr et al., 1991 have shown that salinization has been present in the Great Hungarian Plain at least 30,000 years before. Bicarbonates, carbonates and other ions with alkaline hydrolysis dissolved in the groundwater and in soil solutions were responsible for almost irreversible sodium exchange processes.

CLASSIFICATION OF HUNGARIAN SALT-AFFECTED SOILS

In the late US classification of SAS, the term "white alkali soil" stood for Solonchak soils and "black alkali" for Solonetz soils. The modern Hungarian soil classification is based on these categories as well. Also the categories like saline, sodic and saline-sodic as suggested by Richards, 1954 p. 1 and de Sigmond, 1938, pp, 255-280, are still in use. In the agronomic practice the limit for a soil to be called SAS is 0.1% soluble salt content, as suggested by de Sigmond, 1938 p. 260 and Richards, 1954 p 1.

The current classification system of Hungarian SAS meets two requirements: it fits the general principles of genetic soil classification, first developed in Russia (described in Gerasimov, 1960) and later further developed in Europe (Kubiena, 1953) and USA (Marbut, 1927, Soil Survey Staff, 1951) up to the middle of the twentieth century, and it keeps the traditional categories of Hungarian SAS.

The Hungarian SAS, belonging to the "Main soil type" of "Halomorphic soils" of the national soil classification system (Szabolcs, 1966) are divided into five soil types: Solonchak soils, Solonchak-Solonetz soils, Meadow Solonetz soils, Deep Mollic Solonetz, Secondary Salt-Affected soils. The following list shows the current "official" classification of the main types of "salt-affected soils" of Hungary (Szabolcs, 1966 and Guidelines, 1989). The acreage of the soil types was calculated from the Agrotopographical Map Database (in short AGROTOPO) database, (described by Várallyay et al., 1985). The map of salt-affected soils as shown by Fig 1 was compiled by Szabolcs, 1974.

These soils are *per definitio* the saline soils, which are mainly located in low-lying areas, typically shorelines of saline/sodic lakes, in the region between the Danube and Tisza Rivers, but also occur in patches east of the Tisza River. These soils are characterized with 60-80 cm deep groundwater table and an average total soluble salt content of 0.3-0.5% at the surface. Dominant salts are sodium-carbonate, -bicarbonate, -sulphate and chloride. There is calcium-carbonate in the whole profile. It is difficult to distinguish horizons in the profile of this soil. These soils are not cropped, but sustain a native halophyte vegetation which is grazed.

Solonchak-Solonetz soils (total area 659 km²)

These saline-sodic soils are also located mostly between the Danube and Tisza Rivers, but above deeper groundwater level, ca at 1m. In the profile a weakly developed columnar/prismatic natric (=solonetzic) B horizon can be distinguished. There is calcium-carbonate in the whole profile. These soils sustain a native halophyte vegetation which is grazed.

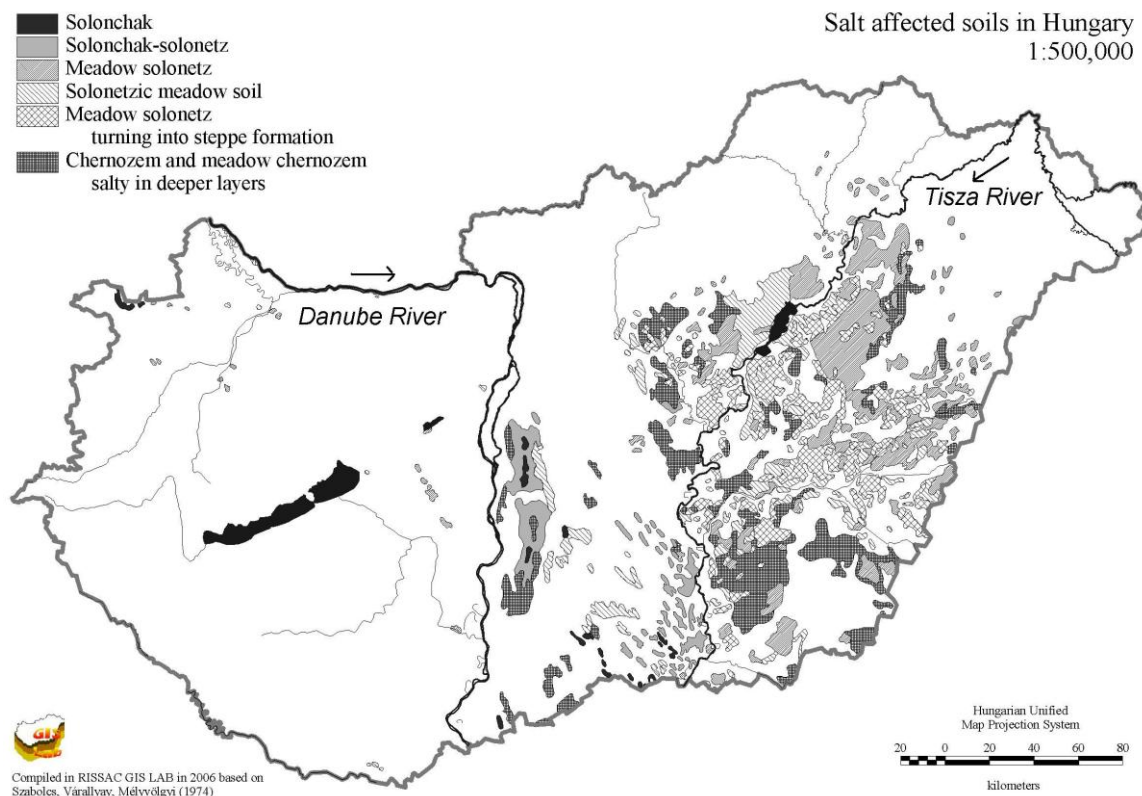


Fig. 1. Map of Hungarian salt-affected soils as published by Szabolcs, 1974
 Solonchak soils (total area 47 km²)

Meadow Solonetz soils (total area 2,749 km²)

The typical "solonetz" soils of Hungary are the typical sodic soils on the Great Hungarian Plain, mostly east of the Tisza River, but also west of the Danube River. These soils are characterized by high values of Exchangeable Sodium Percentage (ESP) and low salt content. This latter can be low enough in the "A" horizon to permit cultivation on these soils. Otherwise these soils sustain a native halophyte vegetation which is grazed. Fertility of soil is proportional to the thickness of slightly saline "A" horizon. In the characteristic columnar/prismatic natric B₁ horizon the value of exchangeable sodium percent (ESP) is 20-25%. The maximum salt accumulation can be found in the B₂ horizon, where the soil structure is prismatic or "nutty" (=large subangular blocky). Calcium-carbonate is generally absent from the A and B₁ horizons. The depth to the groundwater table is between 150 and 350 cm.

Deep Mollic Solonetz (total area 2,122 km²)

When the groundwater table is lower (3-4 m below the soil surface) leaching reduces the amount of soluble salts and calcium-carbonate in the upper horizons of these sodic soils. "Turning into steppe formation", the term originally used for this soil type by Szabolcs, 1966 denotes soil forming processes similar to those of the steppe (Chernozem) soils. These soils are typically ploughed.

Secondary salt-affected soil (not distinguished on the AGROTOPO database as polygons)

This soil type comprises all soils, which were originally not salt-affected, but became salt-affected due to human influence and mismanagement.

Besides the mentioned SAS there are other SAS types which do not belong to the main type of "Halomorphic soils", but to other main soil types, such as "Solonetzic Meadow soils" with a total area of 2,419 km², and "Chernozem soils with saline/sodic subsoil", with a total area of 4,185 km². These soils are typically ploughed.

In Hungary the total area of salt-affected soils, based on the AGROTOPO database (printed on the map sheets by the Kartográfiai Vállalat in 1983), is 12,181 km². With this acreage the overall area of SAS covers 13% of the national territory. The map provided by the Hungarian Central Statistical Office in 2006 is

almost the same as published by Stefanovits in 1963, based on his map of the soils of Hungary at the scale of 1:200,000. Although there are differences in the acreages of the distinct SAS types between the two sources, the total acreages, as 11,087 (Stefanovits, 1963, pp 371-3) or 12,181 km² (AGROTOPO), are very similar.

UTILIZATION OF SAS IN HUNGARY

Though the improvement (reclamation or amelioration) of these soils is scientifically feasible, it is a rather costly operation. This is the reason why large tracts of these soils are kept as grazeland or hayfield, land for afforestation, paddy field or fishpond. Most of the Hungarian National Parks have salt-affected grasslands, hayfields, marshes, reedlands, lakes and these provide habitat for protected animals (mainly birds), plants and attract lots of tourists. Many of the protected animals barely find a place for feeding and breeding on other soil types, since most of those are cropped or otherwise intensively utilized. In total some 88 % of the surface of the country has not natural vegetation cover (cropland, tree plantations with exotic species, orchards, vineyards, settlements, roads, etc).

Among the crops that may be grown economically on these soils the most important is winter wheat. It covers above the half of the area of the SAS. Other important crops are winter barley, sunflower, sudangrass, vetch, rice and sometimes maize, sugarbeet and pea.

INFORMATION AVAILABLE ON THE SPATIAL EXTENT OF SAS

There is an outstanding record of collecting soil information in Hungary. The historical past is summarized in several publications (Ballenegger and Finály, 1963). Similarly to what happened in other countries, during the early period of soil mapping, before the First World War, there were two tendencies: special mapping of selected, usually small areas, and preparation of very small-scale maps, based on scarce observations and continental-scale conceptual models. In Hungary, the first Hungarian soil (called agrogeologic at that time) map was compiled in 1861 (Szabó, 1861) for the area of two counties at the scale of 1: 576,000. Few years later the soil map of Tokaj-Hegyalja intended to improve the production of the famous Tokaj wine in the region (Szabó, 1866). A major achievement was the first complete soil map of Hungary prepared by Timkó in 1914. During the pre-war and after-war periods of 1935-1951, the "Kreybig" practical soil mapping was completed and displayed on maps at 1:25,000. From the 1960s the 1:10,000 scale mapping of the agricultural lands was performed. From 1989 no systematic large-scale soil mapping is carried out.

AGROTOPO map database

The first soil spatial database which became available digitally was the 1:100,000 scale AGROTOPO. This database, which was developed in the 1990s, integrates the dominantly small-scale soil related data into digital format, and is organized into spatial soil information systems (AGROTOPO: Várallyay, 1989; HunSOTER: Várallyay et al., 1994; MERA: Pásztor et al., 1998). AGROTOPO provides information of nine properties, such as soil type, soil parent material, soil texture, clay-mineral composition, soil water regime category, soil reaction and carbonate status, soil organic matter stock, depth of solum, soil bonitation value. There are altogether 3,312 polygons for the total area of 93,000 km² of the country. As background to the soil polygons there is a general topographic sheet with landuse categories, elevation contour lines, settlements, waterways, roads, etc.

The 1:25,000 Soil Information System (Kreybig Digital Soil Information System)

The national soil mapping project initiated and led by L. Kreybig was unique, being a national survey based on both field and laboratory soil analyses and at the same time serving practical purposes (Kreybig, 1937). It was carried out between 1935 and 1951, in several stages, because of the Second World War. In the fifties, when the mapping was successfully completed, Hungary was among the first countries in the world to have such detailed soil information for the whole country. These maps still represent a valuable treasure of soil information. The soil and land use conditions were shown jointly on the maps. Three characteristics were attributed altogether to soil mapping units and displayed on each mapsheet. First feature distinguished was land use, both ploughland and grassland was not distinguished. The second one was the chemical reaction shown by colours, and third feature was the physical soil properties of the soil root zone. Further soil

properties were determined and measured in soil profiles. A very remarkable feature of the map series is that it distinguishes three different categories of SAS by colour codes:

Reddish purple colour: SAS suitable for cropping.

Light purple colour: SAS potentially suitable for cropping can be reclaimed with CaCO₃.

Dark purple colour: SAS not suitable for cropping, which cannot be reclaimed with CaCO₃.

The GIS adaptation of soil information originating from the soil maps displayed at 1:25,000 scale is still **under construction** (Pásztor et al., 2006). There is much more utilizable information originating from this survey, than it was processed earlier and published on the map series and in reports, and what is provided by simply archiving them digitally. The surplus information should be exploited by the new technologies provided by GIS and DSM (digital soil mapping) and provide the basis of improved management of the soils.

Genetic soil maps of 1:10,000 scale

In the early sixties a mapping technology was elaborated by the Hungarian soil scientists, soil surveyors and soil-mapping specialists for the large-scale soil survey in order to meet the practical needs for soil information of large farming units (state and co-operative farms), which characterized the Hungarian agriculture between 1950 and 1990. Such maps were prepared for about one-thirds of the area of Hungary, representing two thirds of the cropland (ca 35,000 km²). The mapping reports consist of four main parts: (i) genetic soil map, indicating soil taxonomy units, and the parent material; (ii) thematic soil maps on the most important physical and chemical soil properties; (iii) thematic maps, indicating recommendations for rational land use, cropping pattern, amelioration, tillage practice and fertilization; (iv) explanatory booklets including a short review on the physiographical conditions; description of soils, recommendations for their rational utilization; field description of soil profiles; results of field observations or measurements and data of laboratory analyses (Szabolcs, 1966). These maps were widely and successfully used in Hungary and became an easily applicable scientific basis of intensive, large-scale agricultural production, in spite of the fact that generally these maps were not published in printed form and are available only as manuscripts at the given farming units or at the Plant and Soil Conservation Stations. The large-scale soil-mapping programme was restarted in 1986 within the framework of the National Land Evaluation Programme (Guidelines, 1989). The aim of this Programme was to value the agricultural land based on soil survey at the scale of 1:10,000, but it was also left uncompleted. These huge archives provide appropriate raw material for recent digitally based applications. Spatial soil information systems based on these data could be efficiently used in numerous fields.

Szabolcs (1966) described the methodology to be used in the detailed mapping of soils. For example in the case of SASs this method at the scale of 1:10,000 can be illustrated best with the set of individual map sheets which might make up a complete soil mapping document.

CONCLUSION

The significance of salt-affected soils of Hungary has changed during the centuries. There is a vast amount of experience accumulated on its origin, distribution and characteristics. During the last century major problems of reclamation and rational utilization of the salt-affected soils have been studied. At the moment there are investigation under way such as field research and a lysimeter study for testing the effect of groundwater control techniques, which are considered to be the fundamental issue, being groundwater the direct source of salts. There is a monitoring system with 69 salt-affected soil profiles, which is monitored with yearly frequency. Inside the European Communities, adoption of measures to protect the areas from the threat of soil salinization will promote the general conditions for improving crop production in salt-affected areas.

Acknowledgement

Author acknowledges the assistance of Mr András Szabó in formatting the paper.

REFERENCES

- Bakacsi, Zs., Kuti, L. 1998. Agrogeological investigation on a salt affected landscape in the Danube Valley, Hungary. *Agrokémia és Talajtan*;47:29-38.
- Ballenegger, R. and I. Finály István.1963. The history of soil science until 1944. (in Hungarian) Budapest, Akadémiai Kiadó.
- Böloni, J., A. Kun, and Zs. Molnár. 2003. *Habitat Guide*. Institute of Ecology and Botany of the HAS, Vácrátót, Hungary, p. 186.(in Hungarian)
- de Sigmond, A. de, 1938. The principles of soil science. London.
- Gerasimov, I. P. 1960. The soils of Central Europe and related geographical problems. Izd. AK. Nauk SSSR. Moscow (in Russian)
- Guidelines. 1989. Guidelines to the field-scale mapping of soils. Agroinform. Budapest.
- Hungarian Central Statistical Office. 2006. Environmental statistical yearbook of Hungary 2005. 2006 November. Hungarian Central Statistical Office. Budapest
- Kreybig, L. 1937. The methods of soil survey and mapping used at the geological institute. (in Hungarian) MÁFI. Budapest.
- Kubiena, W. L. 1953. *Bestimmungsbuch and Systematik der Böden Europas*. Stuttgart.
- Lesch, S. M., J. D. Rhoades, D. J. Strauss, K. Lin and M. A. A. Co. 1995. The ESAP user manual and tutorial guide. Version 1.0. USSL Research Report No. 138. U. S. Salinity Laboratory
- Mádlné Szőnyi J., Sz. Simon, J. Tóth, and Gy. Pogácsás. 2005. Connection between surface and groundwaters in the case of Kelemen-lake and Kolon-lake. (in Hungarian) *Általános Földtani Szemle* 30, 93-110.
- Marbut, C. F. 1927. A scheme for soil classification. Proceedings and papers of the I. Intern. Congr. of Soil Sci. Vol IV. Washington.
- Pásztor, L, Szabó J, Bakacsi Zs, László P, Dombos M, 2006. Large-scale soil maps improved by digital soil mapping and GIS-based soil status assessment, *Agrokémia és Talajtan*, 55, 2006; 79-88.
- Pásztor, L., J. Szabó, T. Németh, 1998, 'GIS-based stochastic approach for mapping soil vulnerability', *Agrokémia és Talajtan*, Vol. 47, No. 1-4, p:87-96.
- Richards, L. A. 1954. Diagnosis and improvement of saline and alkali soils. USDA Agriculture Handbook 60.
- Soil Survey Staff. 1951. Soil survey manual. USDA-SCS Agric. Handb. 18. U. S. Gov. Print. Office, Washington.
- Stefanovits, P. The soils of Hungary. 2nd Edition. 1963. (in Hungarian) Akadémiai Kiadó. Budapest.
- Szabó, J. 1861. Counties of Békés and Csanád. Description of geological conditions and soil types accompanied with a coloured geological map. *Magyar Gazdasági Egyesület*. (in Hungarian).
- Szabó, J. and J. Molnár. 1865-6. Description and classification of the soils of Tokaj-Hegyalja. *Mathematikai és Természettudományi Közlemények IV*. (in Hungarian).
- Szabolcs, I. (ed.). 1966. Handbook of genetic soil mapping of fields. OMMI. Budapest. (in Hungarian)
- Szabolcs, I. 1974. Salt-affected soils in Europe. Martinus Nijhoff. The Hague. The Netherlands.
- Szabolcs, I. 1989. Salt-affected soils. CRC Press. Boca Raton. Florida.
- Szabolcs, I., K. Darab and G. Várallyay. 1969. Methods of predicting salinization and alkalization processes due to irrigation on the Hungarian Plain. *Agrokémia és Talajtan*. 18 (Suppl.) 351-376.
- Szőőr, Gy., P. Sümegi and É. Balázs. 1991. Sedimentological and geochemical facies analysis of Upper Pleistocene fossil soil zones discovered in the Hajdúság region, NE Hungary. pp. 47-59. In: PÉCSI, M.-SCHWEITZER, F. eds. Quaternary environment in Hungary. Studies in geography in Hungary 26. Akadémiai Kiadó, Budapest, p. 103.
- Tóth, T., and G. Szendrei. 2006. Types and distribution of salt affected soils in Hungary, and the characterisation of the processes of salt accumulation.(in Hungarian). *Topographia Mineralogica Hungariae*. IX: 7-20.
- Várallyay, Gy. 1989. Soil mapping in Hungary. *Agrokémia és Talajtan*. 38. 696-714.
- Várallyay, Gy., Szabó, J., Pásztor, L. and Michéli, E. 1994. SOTER (Soil and Terrain Digital Database) 1:500,000 and its application in Hungary. *Agrokémia és Talajtan*. 43. 87-108.
- Várallyay, Gy., Szücs, L., Zilahy, P., Rajkai, K. and Murányi, A. 1985. Soil factors determining the agro-ecological potential of Hungary. *Agrokémia és Talajtan*. 34. Suppl. 90-94.

