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AGROPHYSICAL METHODS OF WATER RETENTION CONTROL IN THE RURAL AREAS

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A b s t r a c t. Main topics and various remarks to resolve flood problems in Central Europe and agrophysical methods of water retention control in rural areas is shown.

K e y w o r d s: agrophysical methods, flood control

INTRODUCTION

The tragic flood in Central Europe which happened in July 1997 and dramatically concerned Poland, the Czech Republic and Germany has stimulated a search for methods to decrease the effects of such floods by agrophysical methods of water retention control in rural areas.

Drafts of the Resolution of the 6th International Conference on Agrophysics (September 15-18, 1997, Lublin, Poland) [4,5] and the final conclusions from an international seminar held in Lublin and Wrocław in March 24-26, 1998 on "Alleviating the needs in specific rural areas damaged by the summer floods of 1997" [1] has suggested to us further activity for increasing soil water retention in rural areas which will be the basis of international multilateral projects.

MAIN TOPICS OF THE RESOLUTION OF THE 6th ICA

There is an urgent need to solve the following practical problems:

- How to restrict erosion by wind and water and the impoverishment of soils through mobilisation and leaching of plant nutrients.
- How to avoid excessive deposition and accumulation of sediment, organic and inorganic compounds, including pollutants. This point is made with specific reference to the recent widespread flooding and soil pollution in the Oder valley.
- How to avoid severe disruption of the soil biological population. Loss of soil biological diversity will also lead to physical and chemical deterioration.
- For remedial methods to be effectively and economically carried out, it is necessary to identify the distribution of degraded soils and to follow remediation by adequate monitoring.

Cooperative work should begin as soon as possible with bilateral or multilateral activities between institutions in the most affected countries or regions, and combined with further approaches at an international level where cross border problems occur.

VARIOUS REMARKS TO DRAFT RESOLUTIONS

General

1. Mapping of erosion and deposition (kind of deposits); visible (erosion, deposits) and non-visible (impurities) effects of flooding.

2. Flooding by big and small rivers - different aspects.
3. Negative and positve effects of flooding.
4. Frequency (time scale) of flooding - frequents and rares.
5. Reversability (time) or not reversability of changes after flooding.
6. Intensity of rain.
7. Important effects of flooding, e.g. loss of main soil characteristics under long flooding, changes in biodiversity of soils.

Polish agrophysics, soil science and agrochemistry

Expected effects of soil flooding

1. Mechanical transport of soil material, erosion, sediment accumulation.
2. Leaching or increase and mobilization or immobilization of nutrients and toxic elements.
3. Chemical and microbiological pollution of soils.
4. Temporary soil anaerobiosis and the resulting increase of anaerobic bacteria activity and intensity of reduction processes.

Immediate activity

1. Evaluate losses caused by mechanical damage of flooded soil profiles, especially in the case of denudation (erosion) of plough-humus horizons and transport of soil material.
2. Evaluate changes of soil nutrient availability and degree of soil and plant pollution with chemical and microbial substances.
3. Evaluate physical and chemical changes of soils caused by temporary overmoisture and reduction processes in anaerobic conditions.
4. Cartographic investigations connected with a need for land reclamation and eventual change of soil evaluation classes.
5. Elaborate technological procedure for reclamation of soils degraded with long lasting excessive flooding.
6. Elaborate polluted plant material utilization.
7. Elaborate methodical recommendations concerning measurements of physical, chemical and biological properties of soils and plants subjected to flooding.

Long term investigations

1. Elaborate and verify physico-mathematical simulation and prognostic models of water resources management in watersheds taking into consideration diffe-rent types of land use, especially in the extreme weather conditions.
2. Examine the state of soil compaction in individual soil horizons taking into consideration the presence of impervious layers in the soil profile and excessive compaction of plough horizons.
3. Generate data bases and survey soil nutrient availability, hydrophysical and aeration properties.
4. Elaborate the system for monitoring (agroclimatic stations) necessary for the evaluation of the current state and prognosis of hydrophysical processes.
5. Elaborate a model of extreme water flow in watersheds dangerous from the point of view of flood.

Strategic goals

1. Elaborate proposals for land use subjected to periodical flooding.
2. Form soil water retention, underground and ground water resources. Use of proper cultivation technology increasing retention ability and water permeability of soil, increase surface occupied by natural plant communities - forests, meadows, pastures; giving up peatlands drainage and transforming them into arable lands, their industrial exploitation, preservation of wetlands.
3. Form water balance in areas where extreme rainfall is a climatic regularity (build retention reservoirs and polders).
4. Increase cultivated soil resistance to erosion processes with agrotechnical and physicochemical methods.

Prof. I.I. Lishtvan (Belarussia)

Immediate activity

1. Estimate of humus, heavy metal distribution and pure ground water composition in one meter soil layer afier flooding.
2. Investigate the humus properties transformation in the upper layer of flooding soils.

Long term investigations

1. Investigate the structure, aqueous, thermophysical and mass exchange flooding soil properties.
2. Quantitatively and qualitatively estimate the humus and water soluble ground water composition of flood soils.
3. Developing methods and reclamations for rehabilitating flood soils.
4. Developing computer cartographic methods for estimating the risk level of flooding territory.

Strategic goals

1. Developing recommendations and reclamations for polluted heavy metal, oil products and degraded soils after flooding.

Experts for developing the project program should collect information from all future participants of the project, about research and applied works connected with predicting, controlling and preventing analogical events in their countries including results about variation soil properties after flooding.

Prof. V.V. Medvedev (Ukraine)

1. The elaboration of small scale schematic maps series with the information about Ukrainian soil covering hydromorphism, i.e. the distribution of the soils with different hydromorphic levels, term and frequence of flooding including territories near artificial water reservoirs. It is necessary to work out these schematic maps during the first stage of investigation using existing information. These materials would allow us to evaluate the common situation, to recognize the more often flooded regions, to choose objects for investigation taking into account variety and typification.
2. The study of different genesis soils stability against gley processes development, compaction and other destructive phenomenons due to flooding. Here it is possible to use our Institute's experience as to the methods for determination of the soil stability against some kinds of degradation in the conditions of hydromorphic processes activization (flooding, underflooding, secondary swamping).
3. The renaturalization of drained hydromorphic soils and turf peats. The correct solution of this problem would allow us to rebuild their biospheric functions and improve landscape stability.
4. The elaboration of methodology and methods for monitoring flooded and heavy moistured territories. It is possible to use these materials for preventing and removing the negative influence of flooding on the environment and plants productive process.
5. The development of methods for the quantitative determination of eoclogy-economical damage due to flooding with the use of energetical and other equivalents. Such methods would allow us to ground the proposed operations for soil covering protection in the conditions of flooding, underflooding and secondary swamping.

Prof. C. Simota (Rumania)

1. Compaction of soil horizons following prolonged stagnation of water;
2. Changes in soil Structure;
3. Transport of substances from deposits (ash pits, ash dumps, waste dumps, dirt heaps); due to storm rainfall events to aquatic system;
4. The effect of storm events after prolonged periods of dry weather in earth flowing;
5. Using GIS, remote sensing techniques and simulation modelling to predict the environmental and economical effects of flooding;

6. Linking river flow forecasting models with soil information regarding the runoff processes in the watershed increasing the accuracy of prediction of the models and their spatially and temporal generalization.

Dr. V. Novak (Slovakia)

1. Soil Erosion and deposition of soil particles in landscape leading to morphological changes.
2. Soil structure degradation and soil properties changes due to flooding.
3. Mobilisation, leaching and transport of soil particles, nutrients and organic compounds down along the soil profile, which leads to decrease of soil fertility.
4. Temporary flooding of root systems leading to anabiosis, yield decrease and plants degradation.

The objective of proposed activity is to establish criteria of soil sustainability when soils are flooded as well as to recommend methods of remediation measures.

Prof. K.H. Hartge (Germany)

Serious damage to the water regime as a consequence of unadapted soil treatment after first retreat of flooding water.

THE MODEL OF HYDROPHYSICAL PROCESSES IN SOIL PROFILE

Physical and mathematical models of water and salt transport in soil are one of the most important components of plant growth and crop yield models. Commonly utilised submodels of water and salt movement in the soil are one dimensional models, in which homogeneity of soil profile layers is assumed. In these models for the description of each layer the mean values of physical characteristics are used. These are obtained from the variability analysis of a given parameter. However, in some cases this simplification is too distant from the course of the real flows taking place in heterogeneous layers. One of the main examples of local deviations of the physical properties are the macropores either of biological origin or created as a result of shrinking and swelling processes of the soil. In natural conditions one can observe water flow with chemical solutes and contaminants through macropores down the soil profile in time much shorter than it could be modelled by the solution of Richard's equation. Such a flow is called preferential flow.

Precipitation and intensity of precipitation are the most important parameters of soil profile water balance. Precipitation values give the information about amount of water reaching the soil surface and having the influence on changes of soil water content profile and runoff. Intensity of precipitation determines the amount of water accumulated in soil layers and amount of runoff water. At the standard agroclimatic stations, only cumulative daily value of precipitation is collected as a climatic and agroclimatic information set. The important value of intensity of precipitation can be approximated by lognormal distribution estimated from pluviographic data collected for a given place for a period of a year. This method was elaborated in the Institute of Agrophysics PAS with co-operation of Climatology Department of the Maria Curie-Skłodowska University.

In the frame of EURO-ACCESS (Agro-Climatic Change and European Soil Suitability) project [2] the model of crop growth and yield prediction was elaborated (Fig. 1). Hydrological part of this model is based on one-dimensional Richard's equation. For the purpose of heterogeneity of the soil profile in the Institute of Agrophysics PAS, the model of bypass flow was elaborated and included into the hydrological part of EURO-ACCESS model (Fig. 2). The amount of water which can flow in the macropores (runoff) is calculated on the base of rainfall intensity and actual soil water coefficient of infiltration. In order to take into account a finite time of water infiltration from the macropores into the soil profile the model of the Green-Ampt is utilise as source term in Richard's equation. This method makes it possible to include the preferential water flow model into existing and practically utilise one

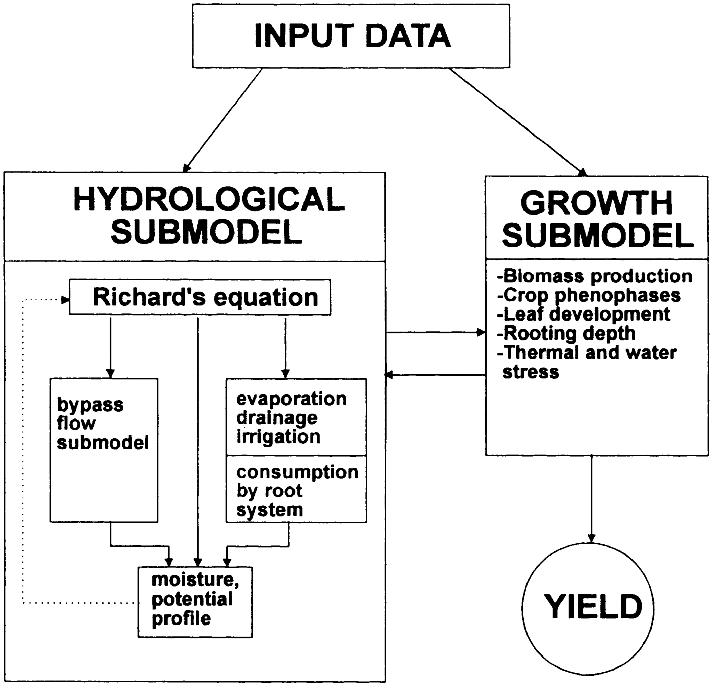

Fig. 1. Scheme of EURO-ACCES II model.

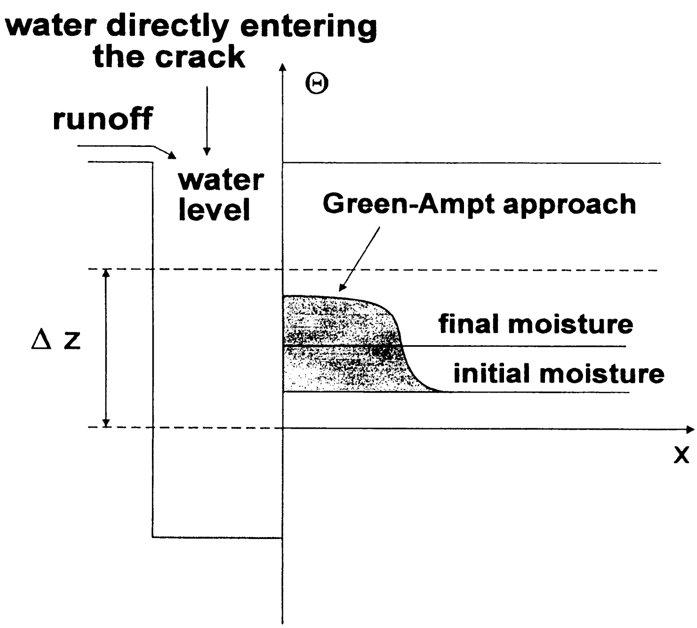

Fig. 2. Scheme of macropore.

dimensional models of water movement in the soil profile. The laboratory and field verifications confirm, that for the correct description of water movement in the soil profile it is necessary to take into consideration bypass flow process.

INVESTIGATION OF WAT ER RETENTION IN THE RURAL AREAS

Increasing water retention in rural areas even on a small scale, may be a significant share in bigger projects concerning flood control [2,3,7,8]. It is possible to search and increase this retention with the use of agrophysical methods.

The proposed elements of such investigations are shown in Table 1.

Regulation of water retention in rural areas requires analysis, monitoring and modelling of natural processes to suggest measures of increasing retention.

The first group of processes (Table 1) appeares in the natural environment and their quantitative description and knowledge of laws which govern their dynamics can be reached through proper observations. This concerns meteorological data, time-spacial monitoring of physical parameters of the soil-plant atmosphere system (Fig. 3) and also surface and under-ground water reservoirs.

Modelling of physical processes in the soil-plant-atmosphere system requires physico-mathematical submodels of mass and energy transport in soil profile taking into consideration erosion processes.

This models make possible simulation of hydrological processes and their modification as a result of changes in some physical properties of the system.

So we can predict the formation of water retention under various agricultural measures which maybe technically realized (e.g., soil loosening and compaction, drainage).

The final practical aim of these investigations are recommendations of measures which regulate water retention keeping in mind their technical and economical conditions.

Elaboration of such models for larger areas is possible only when we have at our disposal a data base on hydrological properties of soils.

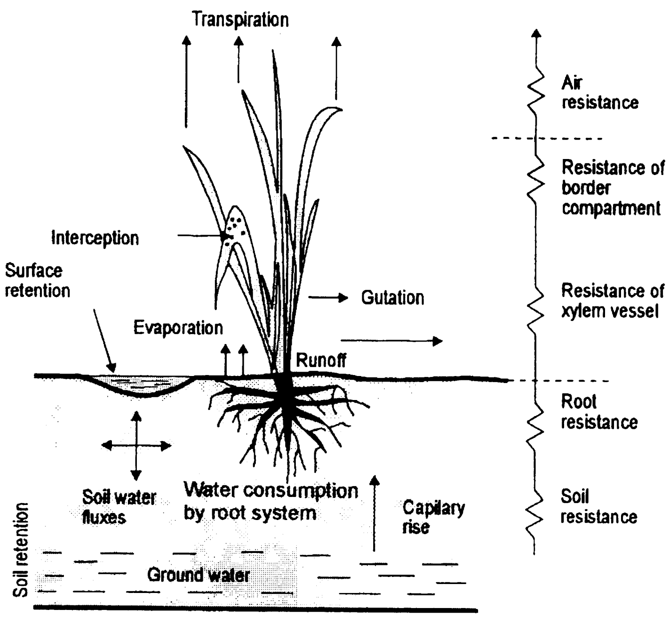

Fig. 3. Water movement in soil-plant-atmosphere system (according to Mazurek [6]).

T a b l e 1. Elements of water retention control in the rural areas

Process	Process observation	Process modelling	Recomendation
1. Rainfall 2. Interception 3. Accumulation in soil profile 4. Infiltration (supplying of ground and deep water reserves) 5. Surface retention 6. Surface runoff 7. Subsurface and ground outflow 8. Small basin retention 9. Large basin retention 10. High and low river water levels 11. Erosion - sediment accumulation	1. Monitoring of agrometeorological parameters . rainfall (intensity) · temperature · thermal balance components . wind speed · water vapour pressure . interception . evapotranspiration . profiles of moisture, temperature, soil water potential, salinity 2. Monitoring of agrophysical parameters of the soil-plant-atmosphere system . retention and water conductivity coefficients · capacity and thermal conductivity coefficients . parameters of salts and contaminants transport 3. Monitoring of ground and deep water levels 4. Measurements of water level and flow rate in water streams and reservoirs	1. Model of water balance and water redistribution in soil profile (point) with submodel of preferential flow 2. Erosion models 3. Hydrological models 4. Models of surface water retention 5. Models of extreme flow rates in river basins 6. Creation of · data bases and hydrological maps · retention and water conductivity in saturated and unsaturated zones · vulnerability to degradation in anaerobic conditions	1. Agrotechnical measures optimising soil physical properties 2. Hydrotechnical management and redistribution of water reserves in soil and landscape 3. Natural measures forming landscape retention

In regulation of water retention of soil the role of man is significant. Building of retention reservoirs protects again floods, but regulation of rivers and land reclamation through a decrease of landscape retention, contributes to floods. A proper formation of physical properties of the upper soil layers towards an increase of water accumulation in soil plays also an important role in counteracting flood hazards.

To carry out a complex investigations of processes connected with water retention and its control in the rural areas it is necessary to chose proper small basins under agricultural cultivations.

These basins should be located in specific soil-climatic regions of a given country.

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