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WIND EROSION IN THE UNITED STATES

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Introduction

The purposes of this report are to give a brief historical perspective on wind erosion in the United States and then to summarize both the current extent of the problem and research efforts to develop wind erosion prediction technology.

The presence of large areas of loess soils in the United States confirms that wind erosion and deposition were important geologic processes in past times. Nevertheless, the activities of man often accelerate wind erosion, and dust stroms have been reported by farmers since the earliest settlements in the United States (**Lyles** 1985). However, widespread plowing of the prairie soils in the semi-arid plains regions followed by the severe drought in the 1930's resulted in "black blizzards". These storms made life on the plains harsh and also deposited large amounts of topsoil on eastern regions of the country, including the capitol, Washington, D.C. (**Hurt** 1981).

A qualitative understanding of the principles of wind erosion control was known before the 1930's. These principles include: a) establish and maintain vegetation or vegetative residues, b) produce or bring to the surface nonerodible aggregates or clods, c) reduce field length along the prevailing wind direction, d) roughen the field surface, and e) protect fields with wind barriers. Nevertheless, the dust storms of the 1930's brought widespread public recognition that both additional research and implementation of control measures were needed.

Two events in the 1940's marked the beginning of the modern era of quantitative research on wind erosion in the United States. These were the publication of a book by British physicist, R.A. **Bagnold** (1941) and establishment of a USDA wind erosion research project at Manhattan, Kansas.

Extent of problem

Cropland

On cropland, about 70 million ha are eroding at rates that exceed twice the tolerance level for sustainable production (USDA 1989). Sheet and rill erosion by water cause 60 percent of the soil loss, and wind erosion causes 40 percent. Cropland regions where

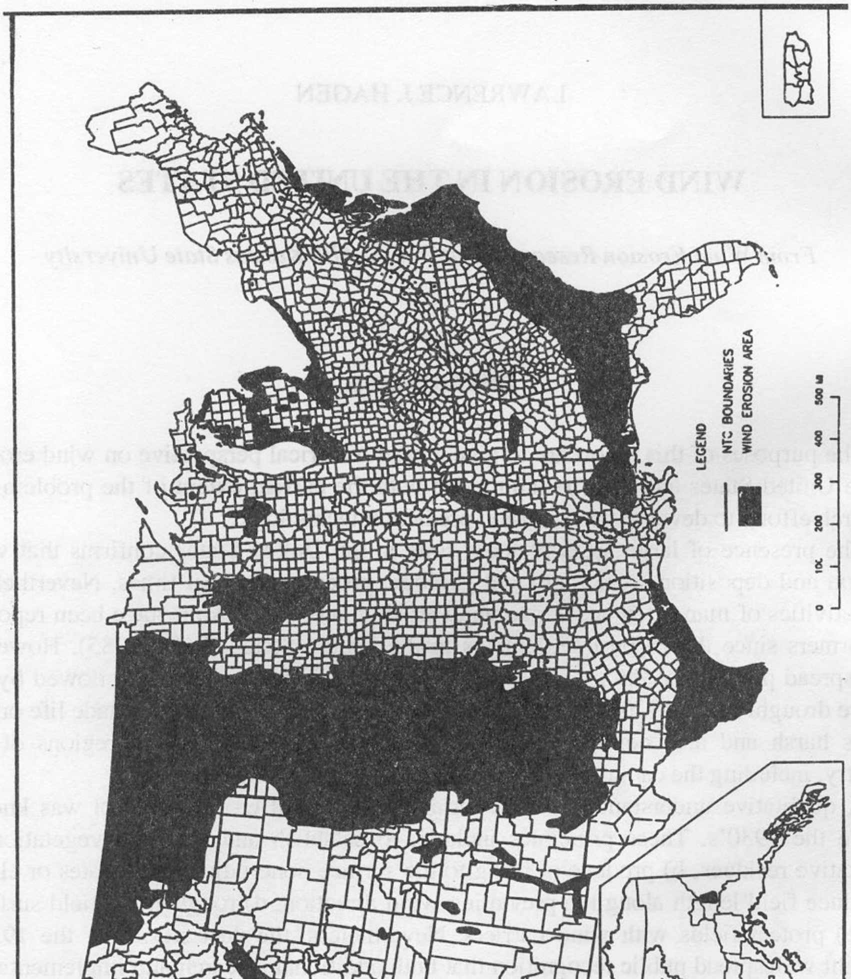

Fig.1 United States areas where wind erosion occurs on cropland
Ryc.1. Występowanie erozji eolicznej na terenach uprawnych USA

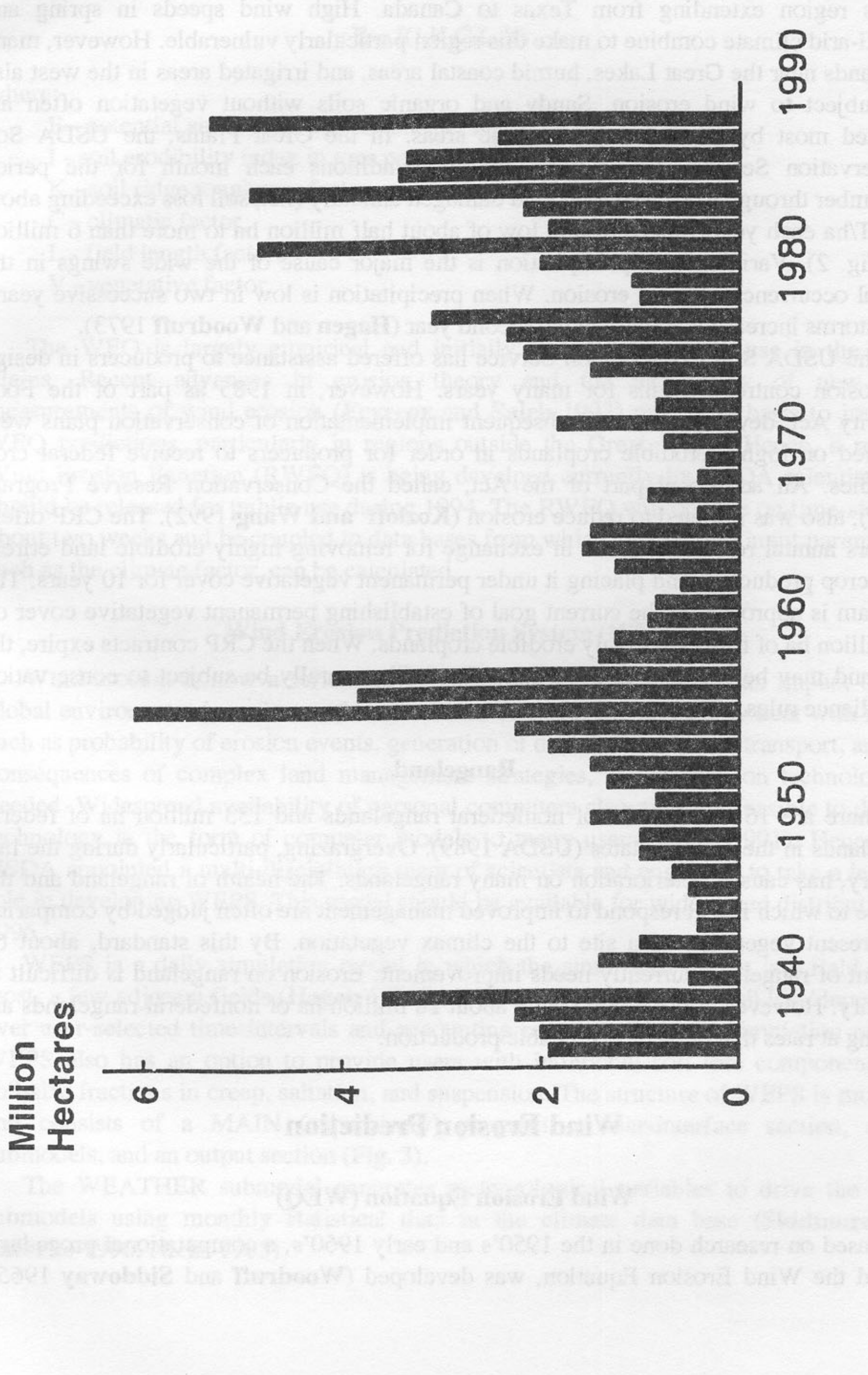

Fig. 2. Land damaged annually by wind erosion in the Great Plains
Ryc. 2. Powierzchnia erodowanych wietrznie pól Wielkiej Równiny w poszczególnych latach

wind erosion is a problem have been summarized by the USDA Soil Conservation Service (Fig. 1). The largest cropland region affected by wind erosion is in the Great Plains region extending from Texas to Canada. High wind speeds in spring and a semi-arid climate combine to make this region particularly vulnerable. However, many croplands near the Great Lakes, humid coastal areas, and irrigated areas in the west also are subject to wind erosion. Sandy and organic soils without vegetation often are affected most by wind erosion in these areas. In the Great Plains, the USDA Soil Conservation Service reports wind erosion conditions each month for the period November through May. The total land damaged annually (i.e., soil loss exceeding about 34 mT/ha each year) ranges from a low of about half million ha to more than 6 million ha (Fig. 2). Variability of precipitation is the major cause of the wide swings in the annual occurrence of wind erosion. When precipitation is low in two successive years, dust storms increase markedly in the second year (**Hagen** and **Woodruff** 1973).

The USDA Soil Conservation Service has offered assistance to producers in design of erosion control systems for many years. However, in 1985 as part of the Food Security Act, development and subsequent implementation of conservation plans were required on highly erodible croplands in order for producers to receive federal crop subsidies. An additional part of the Act, called the Conservation Reserve Program (CRP), also was initiated to reduce erosion (**Kozloff and Wang** 1992). The CRP offers farmers annual rental payments in exchange for removing highly erodible land etirely from crop production and placing it under permanent vegetative cover for 10 years. The program is approaching the current goal of establishing permanent vegetative cover on 15 million ha of formerly highly erodible croplands. When the CRP contracts expire, the cropland may be returned to production, but will generally be subject to conservation compliance rules.

Rangeland

There are 164 million ha of nonfederal rangelands and 133 million ha of federal rangelands in the United States (USDA 1989). Overgrazing, particularly during the last century, has caused deterioration on many rangelands. The health of rangeland and the degree to which it will respond to improved management are often judged by comparing the present vegetation of a site to the climax vegetation. By this standard, about 60 percent of rangeland currently needs improvement. Erosion on rangeland is difficult to quantify. However, it is estimated that about 28 million ha of nonfederal rangelands are eroding at rates that prevent sustainable production.

Wind Erosion Prediction

Wind Erosion Equation (WEQ)

Based on research done in the 1950's and early 1960's, a computational procedure, named the Wind Erosion Equation, was developed (**Woodruff** and **Siddoway** 1965).

WEQ is currently the most widely used method of estimating wind erosion in the United States. The WEQ is expressed in functional form as:

$$E = f(I,K,C,L,V) \quad (1)$$

where:

- E - potential annual soil loss in tons per ha,
- I - soil erodibility index in tons per ha,
- K - soil ridge roughness factor,
- C - climatic factor,
- L - field length factor,
- V - vegetative factor.

The WEQ is largely empirical and initially was developed for use in the Great Plains. Recent advances in erosion theory and the availability of new field measurements of wind erosion (**Fryrear** and **Saleh** 1993) provide a basis to improve WEQ predictions, particularly in regions outside the Great Plains. Hence, a revised Wind Erosion Equation (RWEQ) is being develped currently by USDA scientists and should be released for public use during 1994. The RWEQ will operate on time-steps of about two weeks and be coupled to data bases from which some of the input parameters, such as the climate factor, can be calculated.

Wind Erosion Prediction System (WEPS)

Wind erosion is now a serious problem in many lands, and human impact on the global environment is an issue of international concern. To adequately deal with issues such as probability of erosion events, generation of dust for long-range transport, and the consequences of complex land management strategies, new prediction technology is needed. Widespread availability of personal computers also makes it feasible to deliver technology in the form of computer models to many users (**Shaw** 1991). Hence, the USDA appointed a multi-disciplinary team of scientists and engineers to take a leading role in developing WEPS. This model should be available for widespread distribution in 1996.

WEPS is a daily simulation model in which the simulation region is a field or, at most, a few adjacent fields (**Hagen** 1991b). WEPS output is average soil loss/deposition over user-selected time intervals and accounting regions within the simulation region. WEPS also has an option to provide users with individual soil loss components for soil-size fractions in creep, saltation, and suspension. The structure of WEPS is modular and consists of a MAIN (supervisory) program, a user-interface section, seven submodels, and an output section (Fig. 3).

The WEATHER submodel generates meteorological variables to drive the other submodels using monthly statistical data in the climate data base (**Skidmore** and **Tatarko** 1990, **Nicks** 1985).

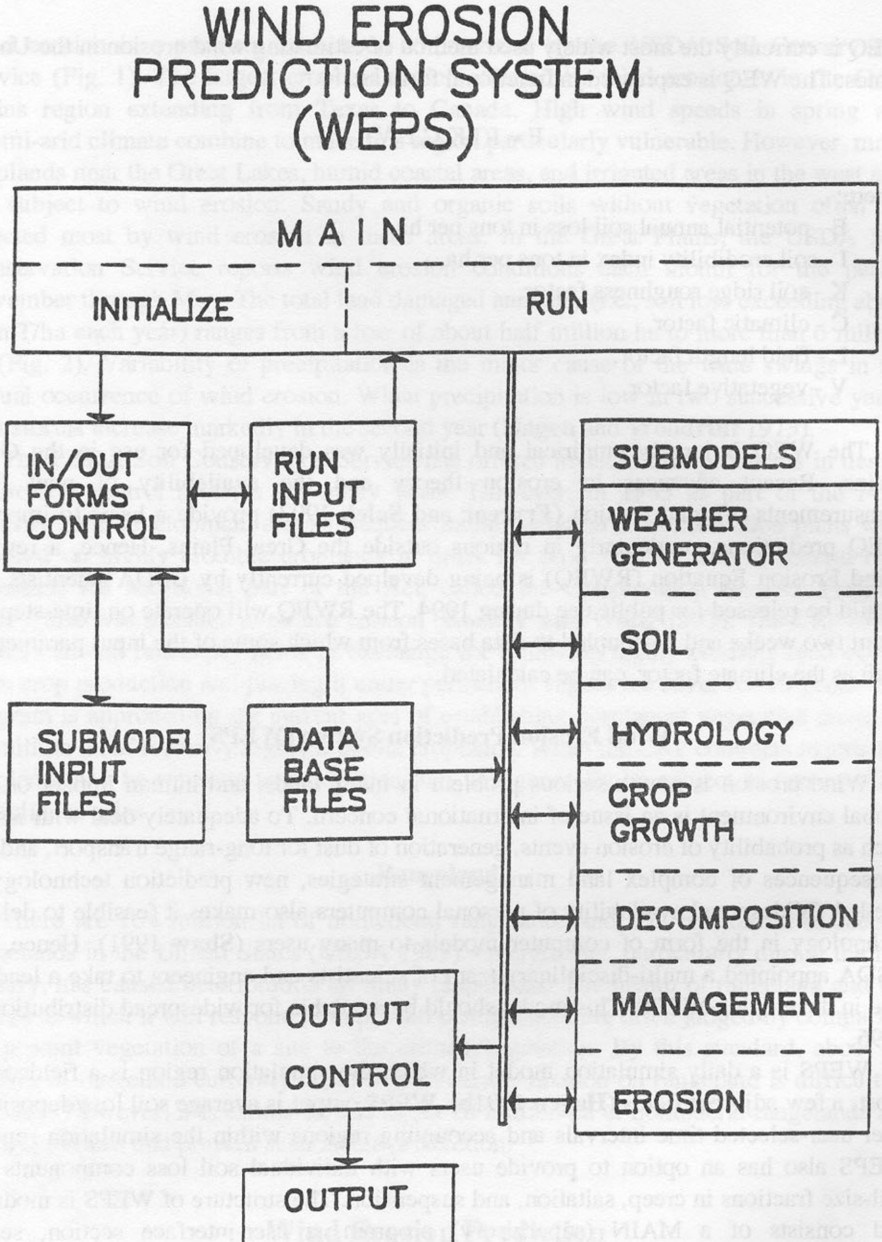

Fig. 3. Wind Erosion Prediction System has modular form with associated files, data bases, and submodels

Ryc. 3. Modułowy System Prognozowania Erozji Eolicznej (WEPS) zbudowany z plików, baz danych i submodeli

Biomass accounting in WEPS is accomplished by the CROP GROWTH and DECOMPOSITION submodels using specific crop parameter values from a data base. Crop growth is simulated by a generalized submodel that calculates potential growth of leaves, stems, roots, and yield components. The submodel uses revised routines derived from the EPIC model described by Williams, Jones, and Dyke (1988). The potential growth is modified by temperature, fertility, and moisture stresses. The DECOMPOSITION submodel predicts the biomass residues in the standing, flat, and buried categories; harvest removes biomass from some of the categories. The SOIL submodel predicts the temporal soil properties between erosion and tillage events. The temporal properties include scales of random and oriented roughness; size distribution and dry stability of aggregates; thickness, dry stability, and cover fraction of crust/consolidated zone; and mass of loose, erodible particles on the crust (**Zobeck** 1991).

The HYDROLOGY submodel simulates the soil water with particular emphasis on surface soil wetness (**Durar** et al. 1993). In addition, energy balances including soil freeze/thaw cycles, snow melt and redistribution, and irrigation will be simulated in this submodel.

The MANAGEMENT submodel modifies the soil and biomass properties by tillage, harvest, burning, etc. (**Wagner** and **Ding** 1993). The management data base consists of parameters for specific tillage and harvesting equipment.

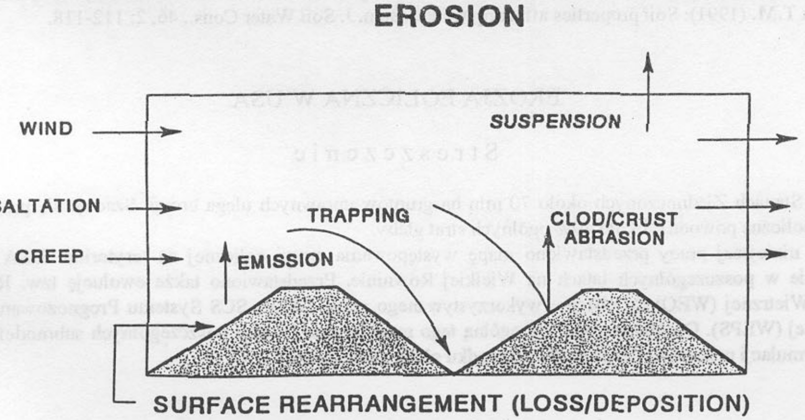

Fig. 4. Processes simulated in WEPS EROSION submodel with a bare soil
Ryc. 4. Proces symulowany w submodelu EROZJA, WEPS-u, dla nieosłoniętej gleby

The EROSION submodel simulates soil loss and deposition during periods when wind speed exceeds the erosion threshold. Soil transport by wind is modeled as conservation of mass of two species (saltation- and creep-size aggregates) with two sources of erodible material (emission of loose soil and abrasion of clod/crust) and two sinks (surface trapping and suspension) (**Hagen** 1991a) (Fig. 4).

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EROZJA EOLICZNA W USA

Streszczenie

W Stanach Zjednoczonych około 70 mln ha gruntów uprawnych ulega erozji. Szacuje się przy tym, iż erozja eoliczna powoduje około 40% ogólnych strat gleby.

W niniejszej pracy przedstawiono mapę występowania erozji eolicznej na terytorium USA oraz jej natężenie w poszczególnych latach na Wielkiej Równinie. Przedstawiono także ewolucję tzw. Równania Erozji Wietrznej (WEQ) do obecnie wykorzystywanego przez USDA SCS Systemu Prognozowania Erozji Eolicznej (WEPS). Omówiono budowę ogólną tego modelu oraz funkcje poszczególnych submodeli, jak też efekt symulacji procesu eolicznego dla przypadku gleby nieosłoniętej.