Pulverizing Erosion Prediction Model

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Wind erosion has become a more important factor in the present soil forming process occurring in the lowland areas of Middle Europe (Ester 1984, **Kostrzewski** et al. 1994). It is caused by global changes in climate as well as by the intensification of agriculture in this area. According to Seifert (1936), changes in the climate of Middle Europe were caused mainly by rapid deforestation (from above 40% in XVI to 20% in XIX century) and by intensive land reclamation works done in order to drain wet soils and marshes. Also in the Wielkopolska Region great drainage works conducted in the Obra and Notec' river basins at the beginning of the XIX century led up to alteration of the natural landscape and worsening of the water balance. The impact of this together with deforestation was so great that it has been advanced that Wielkopolska and Kujawy acquired the characteristic of a steppe (Wodziczko 1947). New techniques of soil tillage reported in most countries of this Region in the 1960's resulted in the stimulation of the wind erosion process. As mechanization and effectiveness of cultivation increased, the field area expanded, and roadside and field trees were removed, the menace of wind erosion developed (Czarnowski 1956, Sommer 1984).

Research on the influence of mechanical cultivation on the wind erosion of light soils proved that in the Wielkopolska Region the wind erosion processes generally take place on light soils with low mechanical strength of aggregate structure. This strength is mainly determined by the particle size distribution, exactly by clay content. These soils are subject to wind erosion when the energy of wind is reinforced by the energy of tillage. It happens especially during shallow tillage treatments at low soil moisture level **(Hagen** et al. 1995, **Podsiadlowski** 1995).

Results of a passive experiment established in Wielkopolska in 1986 indicate that the intensify of wind erosion amounts here from 5 to 20 ton/ha per year. Soil removed from fields is deposited along roadside shelter belts typical of the Wielkopolska landscape. The direct effect of wind erosion is that drainage ditches are covered up by dust. A clear change in the size distribution of soil aggregates and the humus content in the cultivated soil layer of an eroded field is the indirect effect of wind erosion. In certain cases, physical degradation of the soil that hampers proper 'utilization of the land (**Mocek** et al. 1994).

The objective of this work is to present a computer program PEPM *(Pulverizing erosion prediction model).* The program is based on the results obtained in the Research Project ***Impact of tillage upon pulverizing erosion of a silty light loamy sand*** (Maria Sklodowska-Curie Fund II, 1991-1993, cooperation with Dr. Lawrence J. Hagen).

Overview of model

The PEPM was created with the purpose to facilitate prediction of the intensity of pulverizing erosion occurring as a result of tillage on light soils at the low level of soil moisture. The program is based on the following assumptions:

(1) the soil under cultivation is loamy sand with the low level of soil moisture at the top layer;
(2) a tractor used has a four-wheel drive and a board computer (there is an increasing number of such tractors in Wielkopolska, especially in the farms over 100 ha); and

(3)the basic technical characteristics of a tractor and a farm machine are known (mass, power rating, a width of tractor wheels, mass, width and depth of work of the machine).
The PEPM program also allows the approximate prediction of the intensity of wind erosion induced by tillage and by pulverizing erosion. This option is based on additional assumptions:
(1)farmer uses this option in the fields which are subject to wind erosion (our survey indicates that farmers have good knowledge in this matter); and
(2)wind erosion prediction uses a short-term weather forecast available from TV.
The PEPM program was written in a C language. It includes three submodels:
(1)for predicting the expenditure of unit tillage energy,
(2)for predicting the intensity of pulverizing erosion and (3) the intensity of wind erosion (Fig. 1).

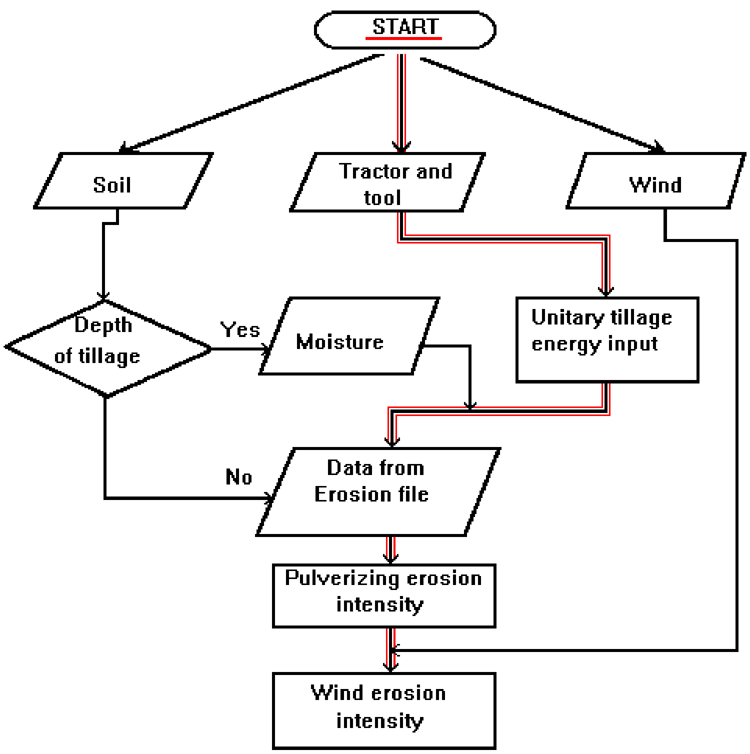

Fig. 1 Diagram of pulverizing erosion prediction model (PEPM) with associated files, data bases, and submodels.

Submodel concepts

Unitary tillage energy input.
This submodel is based on the algorithm for accurate calculation of the tillage energy for any type of farm tractors and machines. Changes in the soil aggregates structure depend mainly on the unitary tillage energy inputs along with soil water content and its distribution. They account for aggregate crushing and transport during tillage. There is a boundary value of the unitary tillage energy for every initial physical state of light soil and for tillage depth. Significant changes in the aggregate structure occur when this value is exceeded. At the low level of soil moisture the soil is pulverized and the pulverizing erosion happens. The aggregate crushing process under these conditions is determined by the total tillage energy that includes: the compaction energy of tractor wheels + the tillage energy transmitted by the working elements of farm tools/machines (Fig. 2).

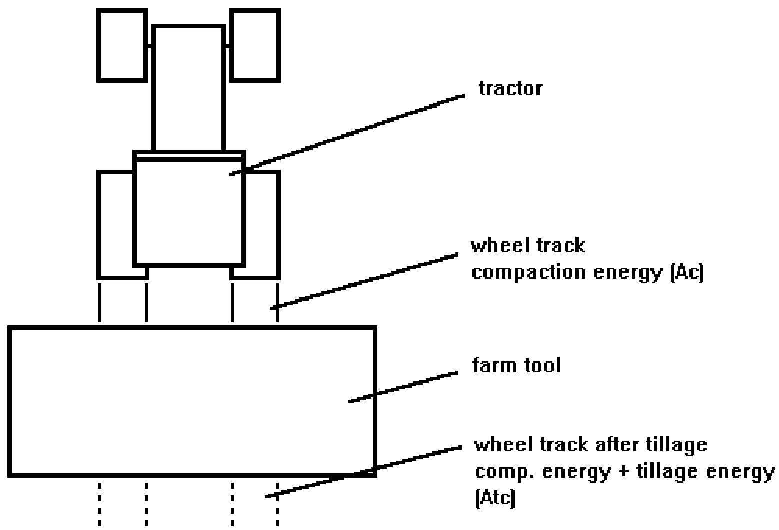

Figure 2 Energy inputs, to create the tractor wheel track and its subsequent tillage.

Energy inputs, to create the tractor wheel track and its subsequent tillage, were formulated:

$$A_{tc} = A_t + A_c \qquad (kJ/m^2) \qquad \textbf{(1)}$$

where:

A_t - unitary tillage energy,
A_c - unitary energy of soil compaction.

$$A_c = \left[A_u - A_t - \frac{(1-E_m)P_t}{E_m W_t} \right] \frac{b}{2b_1} \qquad (kJ/m^2) \qquad \textbf{(2)}$$

where:

A_u - the total energy expenditure per area unit (including also mechanical losses in the tractor), kJ/m^2,
A_t - the tillage energy expenditure per area unit, kJ/m^2,
E_m - the efficiency factor of land wheels power transmission system,
P_t - the total driving force on tractor's wheel axels, kN,
P_{PTS} - the force transmitting shaft from the tractor to the rototiller, kW,
W_t - The surface work efficiency, m^2/s,
b - tillage width, m,
b_t - wheel track width, m.

Unitary tillage energy expenditure is calculated according to the following formulas.

$$A_{t(plough)} = a(k_1 + k_2 * v^2) \qquad (kJ/m^2) \qquad \textbf{(3)}$$

where: a - tillage depth, m,
k_1 - coefficient of the static resistance, kN/m^2,
k_2 - coefficient of a dynamic resistance, kN s^2/m^4,
v- working speed, m/s.

$$A_{t(cultivator)} = a(k_3 + k_4 * v) \qquad (kJ/m^2) \qquad \textbf{(4)}$$

where:

k_3 - coefficient of the static resistance, kN/m^2,
k_4 - coefficient of a dynamic resistance, kN s/m^3.

$$A_{t(harrow)} = k_5 + k_6 * v \qquad (kJ/m^2) \qquad \textbf{(5)}$$

where:

k_5 - coefficient of the static resistance, kN/m,
k_6 - coefficient of a dynamic resistance, kN s/m^2.

$$A_{t(rototiller)} = \frac{a(P_1 + P_2 * v^2) * v_t / v_n}{v} \qquad \text{(kJ/m}^2\text{)} \qquad \textbf{(6)}$$

where:

P_1 - power coefficient related to static resistance, kN/m s,
P_1 - power coefficient related to dynamic resistance, kN s/m^3,
v_t - tangential velocity if a tractor’s wheels, m/s,
v_n - nominal speed, m/s.

Pulverizing erosion intensity

This submodel enables us to predict the intensfty of pulverizing erosion on the base of inputs of unit tillage energy defined previously. Mathematical models describing the pulverizing erosion process on loamy sand were used **(Podsiadlowski** 1995). We took into account work of the following farm machines nad depth tillage: plough (18 and 28 cm), cultivator (5, 10 and 15 cm), harrow (5 cm), rototiller (5, 10 and 15 cm). All mathematical models work under condftions of low soil moisture (0-4%) in the top layer (0-5 cm). In case of tillage at a depth more than 5 cm, the models take into account the soil moisture gradient that is present in the cuftivated layer of loamy sands. A soil moisture gradient expressed as ,,q", is a ratio of soil moisture in a top layer to the average moisture of the cuftivated soil layer.

Wind erosion intensity

This submodel enables approximate prediction of wind erosion intensity on the base of pulverizing erosion intensity defined earlier. The submodel is also based on a short-term weather forecast, mainly wind speed. As computer network systems expand and databases grow the submodel will be improved.

Model validation

This work presents the first version of the Pulverizing Erosion Prediction Model. The model was developed for conditions in the Wielkopolska region. It is intended to be used by farmers having large farms, and modern farm equipment (in the region there is an increasing number of large farms). It is assumed that the reduction of pulverizing erosion will resuft in elimination of the menace of wind erosion. The presented model will be improved. Currently we are working on an additional option, The Soil Conservation for a board computer, which also includes PEPM.

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