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INTEGRATED TILLAGE AS ANTI-EROSION SOIL TILLAGE: RESEARCH PROSPECTS[1]

Michał Czajka[*], Stanisław Podsiadłowski[**], Ryszard Walkowiak[*], Tomasz Wojciechowski[**]

[*] Department of Mathematical and Statistical Methods, [**] Institute of Agricultural Engineering
Poznań University of Life Sciences
Wojska Polskiego str. 28, 60-627 Poznań, stapod@up.poznan.pl

Summary. On intensively cultivated sandy soils in Poland, wind erosion often occurs near the time of ploughing and of the sowing of both spring and autumn crops. The objective of this study was to design and test an integrated tillage system that could reduce the erosion hazard on the low-porosity, loamy sands that constitute a large proportion of cropland in Poland. An integrated system modifies the soil structure and produces a larger fraction of non-erodible aggregates with higher dry-aggregate stability at the soil surface than is the case in conventional tillage. To achieve this, an integrated tillage system was developed that performed ploughing, second tillage, and sowing in a single tractor pass. Next, the system was compared with other tillage systems to determine its relative effects on the tillage energy distribution, soil structure, and potential wind erosion.

Key words: integrated tillage system, second tillage

INTRODUCTION

Wind erosion is one of the major geomorphological processes affecting approximately 548 million ha, especially in the arid and semi-arid zones. A possible occurrence of aeolian processes on the light soils of Wielkopolska was already suggested by Czarnowski [1956] and Wilusz [1957], since the traditionally intensive agricultural production, which is conducted primarily on light soils, had contributed, among other things, to the region's water balance showing a net

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loss (-60 mm). The results of passive experiments launched in Wielkopolska in 1986 to determine the dynamics of changes in the intensity of wind erosion over time (Programme RP-II-15, Soil erosion and methods of its prevention), make it now possible to assess this threat in quantitative terms. As follows from the research carried out on the Kościan Upland, aeolian transport can achieve here an intensity of as much as 150 kg of deflated material per each metre of field width, which corresponds to a loss of about 20 tonnes of soil (mostly dust and fine material) per hectare per year [Podsiadłowski 1991], while a mean annual intensity of aeolian transport higher than 5 $kg \cdot m^{-1}$ leads to significant changes in the physical state of the ploughed layer of the eroded field. Those changes alter the proportions of organic matter [Podsiadłowski 1994], which results from a higher content of organic carbon in the particles undergoing suspension and pulverising erosion than the average for the soil undergoing erosion. An all-round study of a deflation-exposed field at Wierzenica, carried out since 1996 in co-operation with the Quaternary Research Institute of Adam Mickiewicz University in Poznań, has shown that wind erosion also crucially affects the particle size distribution of the ploughed layer of the field [Stach and Podsiadłowski 2002].

Wind erosion leads directly to the formation of extensive zones of deflation and accumulation (ditch levelling) and to a drop in the productivity of erosion-exposed fields. Studies of how the mechanical cultivation of light soils contributes to wind erosion have shown that in the Wielkopolska conditions this process practically only occurs on light soils – loamy sands – in the period of pre-sowing practices. This is due to the following:

– the aggregate structure of those soils has a relatively low mechanical strength,

– during conventional cultivation the topsoil is subjected to both tillage energy and kneading energy coming from the tractor wheels, and

– the second tillage of light soils usually takes place in the conditions of a relatively low moisture of the topsoil, which favours destruction and stimulates pulverising erosion.

The recommended method of protecting soils against wind erosion is reduced cultivation. A variety of systems are proposed, depending on soil conditions, the actual threat, and the profitability of production. The so-called conservation tillage involves leaving a proportion of crop residues on the field to reduce wind speed in the near-surface zone [Hagen 1991]. Other suggested systems include no-tillage agriculture, which makes use of the relatively high natural porosity of the monofractional soils cultivated [Crovetto 1996]. Reports of its successful applications come, as a rule, from areas with this type of soil. By contrast, light soils, like Poland's polyfractional loamy sands threatened with wind erosion, display a relatively low natural porosity (32–37%). Also, they are cultivated rather intensively, and a big role in crop rotation is played by plants responding poorly to low porosity of the ploughed layer at the start of the vegetation period (root crops, barley).

That is why in 1996 a wide-ranging research was launched at the Institute of Agricultural Engineering of the Poznań University of Life Sciences (in co-operation with the USDA) to find a way of reducing the detrimental effect of mechanical cultivation on the aeolian stability of the surface of tilled fields. The result is a proposal of so-called integrated tillage which makes it possible to obtain soil aggregates on the field surface that show a relatively high mechanical strength. The aim of this paper is to present the current state of research on this type of cultivation as well as studies we are planning to launch in the nearest future.

Integrated tillage. The essence of the proposed system is the performance of ploughing, second tillage, and sowing in a single tractor pass (Fig. 1).

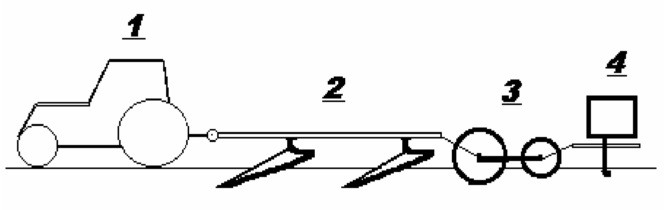

Fig. 1. Components of the integrated tillage system: 1 – tractor, 2 – mouldboard plough, 3 – rollers, 4 – sowing machine

Integrated tillage offers the following advantages:

– the tractor only moves over a soil which still has a compact structure, which means that its wheels do not knead the soil that has already acquired an aggregate structure,

– the elimination of ruts allows a relatively free moulding of the total porosity of the ploughed layer, in accordance with the requirements of crops and a meteorological forecast,

– the double elimination of ruts also makes it possible to reduce the total input of unit tillage energy and in consequence to reduce fuel consumption, and

– the reduction in the total input of unit tillage energy and its performance in the conditions of a stable (usually average) moisture level makes it possible to achieve a relatively high proportion of large aggregates in the topsoil, which lowers the probability of wind erosion [Hagen *et al.* 1999].

CONDITIONS AND METHODS OF STUDY

The fieldwork was carried out in 2009 at Wierzonka, 20 km east of Poznań, in the zone of the Leszno Stadial of the Baltic Glaciation. The deflation field chosen is 57 ha in area and has for years been under cropland regime typical of light soils. Despite its shelter belts on the outside (roadside trees along three sides) and inside (three mid-field tree clusters), the field shows susceptibility to wind erosion [Podsiadłowski 1995]. An earlier determination of the spatial variability of the particle-size distribution [Stach and Podsiadłowski 1998] allowed a precise selection of the object of study (Tab. 1).

Table 1. Particle-size distribution of soils from the Wierzonka field

Fraction content, %					
> 2.0 mm	2.0–1.0 mm	1.0–0.1 mm	0.1–0.05 mm	0.05–0.002 mm	< 0.002 mm
2.6	5.4	56.2	14.4	19.3	2.1

In the study use was made of a Ursus U-904 tractor with a power rating of 63 kW, weight of 5.650 kg and typical tyres (12.4/11-24, 184/15-34). The integrated tillage set weighing 820 kg consisted of a U023/1 plough, a roller section (Campbell + Croskill), and an S033 precision seed drill. The input of unit tillage energy (Et) was calculated using the STAPOD program based on an algorithm provided by Krysztofiak *et al*. [1998]. The methods employed were those generally applied in soil science. The force initiating aggregate breaking was measured using the method described earlier [Podsiadłowski *et al*. 2003].

RESULTS

What makes it particularly difficult to simplify the cultivation of loamy sands in order to lower their susceptibility to erosion and reduce energy inputs is the generally low natural porosity of polyfractional soils. An additional factor is the relatively low strength of the aggregate structure of those soils, which contributes directly to the intensity of pulverising erosion [Podsiadłowski 1995]. Moreover, as it is well known, the strength of tractive adhesion to the surface is one of the major factors controlling a tractor's effective towing power, today the basic source of tillage energy. In the traditional tillage system it is hard to reduce the unit energy of compaction, transmitted as it is to the soil via the wheels, without simultaneously diminishing the effective towing power, which is after all a tractor's basic utility parameter. A tractor moving on a soil which has already an aggregate structure, a loosened soil, produces ruts of varying depth using considerable amounts of energy in the process. That is why, for example, the proportion of unit tillage energy E_t, i.e. the energy used for soil cultivation only, to total unit energy, which also embraces unit compaction energy, is so low in the second tillage. In this type of tillage, the high compaction energy transmitted to the soil by the ground wheels usually has a detrimental effect on the physical state of the soil in the ploughed layer, producing destruction and zones of excessive compaction, as well as stimulating deflation and erosion. Therefore it was decided to completely eliminate soil kneading by the tractor wheel system, which is possible in the case of integrated tillage.

It is generally believed that soil aggregates larger than 0.84 mm are resistant to wind action. The proportion of this fraction in the topsoil is considered to be an index of the deflation susceptibility of a field [Hagen *et al.* 1992]. In the cultivation of wind-threatened soils, efforts focus on making this proportion reach at least 50% by volume. An earlier study conducted on loamy sands [Podsiadłowski and Hagen 1995] shows that, unlike conventional cultivation, integrated tillage can ensure an aeolian stability of the field surface in such conditions. The question that remains is the permanence of this state, given the relatively low mechanical strength of the aggregate structure of loamy sands. An answer was sought in a research whose results are presented graphically in Fig. 2.

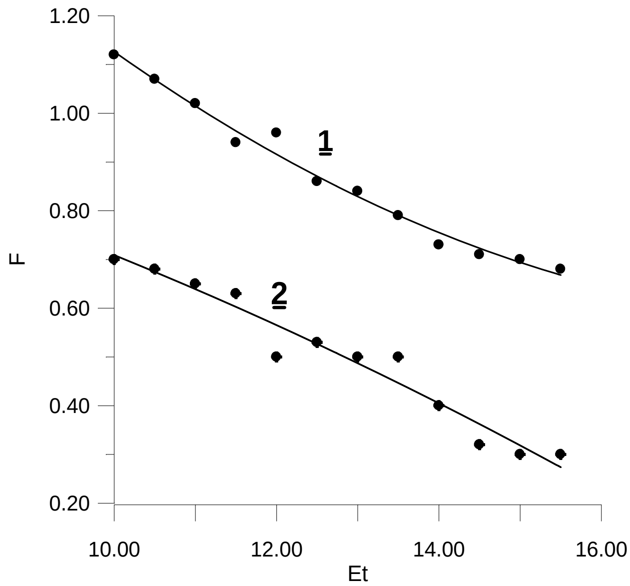

Fig. 2. Effect of unit tillage energy E_t (kJ $\cdot$ m^{-1}) on the aggregate break-force F(N) of a non-erodible soil fraction (sieve diameter range of 2–3.15 mm): 1 – integrated tillage, 2 – conventional tillage

The results corroborate those obtained earlier in a study on the breaking energy of larger fractions of light-soil aggregates [Podsiadłowski *et al.* 2003]. Mechanical tillage of this soil, expressed by unit tillage energy (kJ·m^{-2}), clearly affects the mechanical strength of the 2–3.15 mm fraction in each of the systems considered. However, in the case of integrated tillage, this strength as expressed by the aggregate break-force is about 1.5 times greater than in traditional tillage. This means that the intensity of mechanical tillage and its mode have a direct effect on the quantitative and qualitative characteristics of the developing aggregate structure that determine the susceptibility of light soils to erosion.

CONCLUSIONS

The traditional intensive cultivation of light soils with its several sequential applications of tillage and kneading energies to the topsoil leads, on the one hand, to the development of zones of excessive, usually detrimental, compaction, and on the other, to soil destruction and the stimulation of aeolian processes. Integrated tillage, with ploughing, second tillage and sowing or planting in a single tractor pass, makes it possible to avoid a substantial part of those unfavourable cultivation effects. The tractor does not waste energy on making ruts, which is the chief fuel-saving asset of this system, not to speak of soil protection. In addition, the wide range of adjustment of the roller section makes it possible to control compaction parameters in the created soil profile practically freely, in accordance with the requirements of a given crop. The aggregate structure being formed on the field surface displays not only a favourable proportion of large aggregates giving it resistance to deflation, but also considerable stability expressed as a relatively high mechanical strength of aggregates of individual fractions.

The studies of integrated tillage carried out so far have largely concentrated on its role in reducing wind erosion of sandy, polyfractional soils [Hagen *et al.* 1999, Podsiadłowski 2005]. Their results, as well as observations made on several objects in a variety of conditions, suggest undertaking a research on the role this tillage system might play in giving light soils resistance also to water erosion, occurring especially in the end-morainic zone of the Last Glaciation.

The analysis of the results obtained allows the following conclusions to be formulated:

– the intensity of mechanical tillage and the way it is performed have a clear effect on the qualitative characteristics of the aggregate structure of loamy sands,

– integrated tillage markedly lowers the deflation susceptibility of loamy sands and increases their stability, and

– integrated tillage requires further studies to work out a model forecasting the technical conditions of its performance and to examine its usefulness in preventing erosion by water.

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PERSPEKTYWY BADAŃ ZINTEGROWANEJ UPRAWY GLEBY JAKO UPRAWY ANTYEROZYJNEJ

Streszczenie. W Polsce erozja eoliczna występuje często w czasie orki i uprawy popłużnej, na intensywnie uprawianych glebach piaszczystych. Celem badań była konstrukcja i doskonalenie zestawu do zintegrowanej uprawy gleby, który pozwala zmniejszyć ryzyko erozji eolicznej na charakteryzujących się niską porowatością naturalną piaskach gliniastych, stanowiących znaczną część gleb uprawnych w Polsce. Zintegrowana uprawa gleby modyfikuje strukturę gleby, wytwarza na powierzchni gleby większą frakcję agregatów nieerodowalnych w porównaniu z tradycyjną uprawą gleby. Aby to osiągnąć, opracowano metodę zintegrowanej uprawy gleby, polegającą na wykonaniu orki, uprawy przedsiewnej i siewu podczas jednego przejazdu ciągnika. Następnie metodę tę porównano z innymi metodami uprawy gleby.

Słowa kluczowe: zintegrowana uprawa gleby, uprawa przedsiewna