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# WATER EROSION CONTROL IN CONDITIONS OF A GEOMORPHOLOGICALLY DISSECTED AREA

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A problem of landscape consolidation, or land arrangement in conditions of large-scale farming is presented. The pilot area of the Agricultural Manufacture and Trade Co-operative of Kočín, which farms soils regularly damaged prevailingly by water erosion (dominant soil profile Haplic Luvisols from loessial parent material) was treated by comprehensive physical-geographical analysis. Evaluation of the present agricultural practices was also helpful. We have investigated and proposed a system of water erosion control like new landscape arrangement (optimum field size and shape, proposals for a new road network), contour agrotechnics, no-till minimum technics, green corridors and terrace construction.

**Key words:** water erosion, erosion control, landscape consolidation

## INTRODUCTION

In conditions of rolling countryside and soil cover vulnerable to both water and wind erosion, a specific physical-geographical analysis is required. It could identify not only natural conditions in farmland but also actual sheet and gully erosion with their extent and intensity. This analysis with knowledge of the present agricultural practices (e.g. tillage, manure, crop rotation, etc.) can help us to evaluate various proposed erosion mitigation programmes. A comprehensive erosion control programme requires precise arrangement of landscape organiza-

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tion with respect to all relevant geomorphological elements and present agricultural use. This means, there is a need to make distribute and arrange field blocks and routes in a way that reduces soil loss during intensive agricultural utilization as much as possible. At the same time, we have considered a new landscape design to conserve traditional and unique area character, and from the point of view of supporting ecological aspects of landscape stability. The proposed erosion control measures were discussed with the authorities of the Agricultural Manufacture and Trade Co-operative (PVOD) Kočín and some of them should be implemented in practice. The main goal of this study is to propose a new field arrangement with erosion control measures in order to secure soil conservation and ecological stability of the area.

## SITUATION

### Geomorphology

The pilot territory – the PVOD Kočín has an area of 1295 ha of farmland, located at an altitude 170-300 m a.s.l. in the Trnavian Hilly Land. The surface is formed by four mound elevations with NW-SE direction. They are divided in three talwegs. The area is drained by three brooks. Most of the territory (central and southern part) is covered by loess of the Würm age. The area has the character of erosion/accumulation hilly land with average slopes of 3-7° (weak to moderate erosion). The geological structure of the northern part consists of alternating limestones and dolomites with calcareous sands, marlites and calcareous clays. These rocks are frequently overlain by diluvial loams. This part is characterized by markedly undulated hilly land and higher sloping of spine-curves on average 7-12° (strong erosion). Locally we have recognized slopes of more than 15° (extreme erosion).

### Climatic-hydrological conditions

The territory belongs to the warm climatic area, moderately moist with mild winters. The average annual temperature is 9.2° C, and summer days number more than 50. The long-term average precipitation is 625 mm with the maximum in June. Precipitation used to be higher than evaporation, although in recent decades a deficiency was registered. Strong rain events are most frequent in June (end of May); stage of vegetation – wheat blossoming, maize – not higher than 30 cm, quantity not higher than 60 mm, time approximately 20 minutes.

### Vegetation and land use

The area has been intensively utilized for agricultural practices for a long time with a significant share of arable land, less grassland and a minimum of special cultures such as orchards, vineyards and recently also hop gardens. Besides planted deciduous forest communities, there is only a negligibly amount of potential natural vegetation of oak-hornbeam and oak forests and, along the streams, ash-tree and alder forest communities.

## Pedological conditions

The most widespread soil type is modal Haplic Luvisol (482 ha), loamy, locally sandy-loamy, silty, developed from loess, located in the central and eastern part. Stagnic Luvisols (86 ha) developed from polygenetic loams are frequent, occurring in valley slope parts. Eroded Luvisols (360 ha) are situated mainly on convex slope parts and characterized by reduced humus (top) horizon, with approximate thicknesses of 20-30 cm. Albi-Haplic Luvisols (29 ha) developed from polygenetic loams can be found in sloping dissected areas. Typical products of long-term erosion processes are Calcaric Regosols (189 ha) strongly calcareous, with loess presence in the top horizon. They are located on slopes of > 7° (Houšková 1995). Profiles of these soils show loss of top soil, that is decrease in depth of the top layer due to more or less uniform removal of soil material by runoff water. The top horizon is prevailingly thin, with ochric colour, weak structure, etc. Anthropogenic soil representatives are Modal Cultisols with trenched form (62 ha) and gardening form (52 ha). Typical diagnostic characteristics area homogenized cultivated humus horizon which often occurs in vineyards, orchards, gardens and hop plantations. The Morphogenetic Soil Classification System of Slovakia (Sobocká and Šály 2000) was used for classification of soil units.

## Erosion

The main degradation process of the investigated area is sheet and gully water erosion. Its extent is especially associated with large-scale field cultivation and sometimes irrationally applied agronomic technologies. Most of area has loamy, moderately to severely erodible Luvisols, less Calcaric Regosols. Water erosion, that is runoff/accumulation processes are indicated practically on the whole farmland territory. Top material runoff is observed in 87 % of farmland, soil material accumulation in the remaining 13 %. According to Jambor and Ilavská (1998) and Jambor et al. (1995), the following really eroded areas were recognized:

- weakly eroded soils (sloping 0-3°) – 12,3 % of farmland < 25 % of the original A-horizon eroded, loss of 0-4 tons per ha/year;
- moderately soils (sloping 3-7°) – 52,5 % of farmland 25-75 % of original A-horizon eroded, loss of 4-10 tons per ha/year;
- strongly eroded soils (sloping 7-12°) – 21,2 % of farmland > 75 % of the original A-horizon eroded, loss of 10-30 tons per ha/year;
- severely eroded soils (sloping > 12°) – 14 % of farmland, whole original A-horizon and part of the subsoil eroded, loss of > 30 tons per ha/year.

# MATERIALS AND METHODS

In the sense of the works by Laften et al. (1985), Ankenbrand and Schwertman (1988), the following are included under main erosion control measures: conservation tillage, crop rotation, contour tillage, green belt establishment, terracing, intercepting fallows (as waterways), underground runoff, sedimentation reservoirs and (most effective) vegetation cover.

- Conservation *tillage* includes all the types of agrotechnical measures reducing erosional runoff, particularly combination of no-till (minimum-till) with mulching.

- *Crop rotation,* that is a cropping system, favouring crops with good conservation effect by principles of proper crop rotation.
- Contour *tillage* is extensively used in well-modelled sloping terrain. Tillage along contours using a proper turning plough creates the smooth surface important for mechanized technologies, and in the vegetation period it reduces runoff by 50 %.

Further erosion control measures are rarely used in our practice and are sometimes difficult to implement, but according to Landi (1988) they are effective.

- *Irregular step terracing* is formation of irregular terraces in pastures or meadows corresponding to the given relief. The terrace edges are fortified by in situ stones.
- *Hill-riding terracing* is possible in sloping stony terrain with slopes under 20°. Terrace edges are fortified with local stones and are arranged at intervals of 8-14 m. They have regular shape. Water is drained by crossing vegetation fallows.
- *Up and down terracing* is possible in areas, where soils have high clay content, mild slopes and ploughing has a long tradition. Water is drained into cross channels.
- *Herring-bone ditching* is suitable for all types of slopes intensively cultivated, well-modelled with slopes of under 17°. Terraces or small ditches copy convex slopes in trapezium shape, margins are fortified by stones or vegetation belts (e.g. in tree alley form). Water is drained into dense vegetation ravines.
- *Grassy belt terracing* is an old system adapted to the shape of slopes with gradients of 15-19°. Grassy belts are planting on terraces edges. They can be supported by tree planting. Newly formed terraces possess very moderate slopes of 1-2°. Under terrace margins channels are formed for surplus water discharge.
- *Contour trenches and roads* are formed by ploughing 5-10 cm deeper than the topsoil ploughing horizon. Ditch lenght is not greater than 200 m and inter-ditch interval ranges are 60-100 m. The ditches collect surplus water and drain it into cross furrows. Contour ditches are often compensated by contour roads. They have double function – they enable movement of agricultural machinery and water drainage.
- *Grassy belt alternation.* Its principle is annual alternation of crop belts with grassy belts. The main tools of soil mass fixation are grassy belts that keep soil material leached from the strips of crops.

## RESULTS AND DISCUSSION

It is well-known that these measures will have their effect only in the long-term horizon. We have studied almost all available soil conservation measures with the aim of consolidating the landscape and preventing extreme degradation of by erosion. We note, that specific erosion control by crop rotation was not considered in this paper.

### Field shape and size

From the theoretical-methodological point of view it is not desirable to cultivate erodible soils in fields more than 30 ha in area. Therefore there was a need to revise over-sized erodible fields. PVOD Kočín is farmed in area of 1 295 ha, which is divided into 51 farmed fields (field blocks). The largest of them is 119 ha and the smallest is 1 ha. The average field size is 25.4 ha. However this information is not conclusive, as the shapes and sizes of fields are adapted, as a rule, to natural and social conditions, that is small enclaves of grassland and a small-scale private sector are also included.

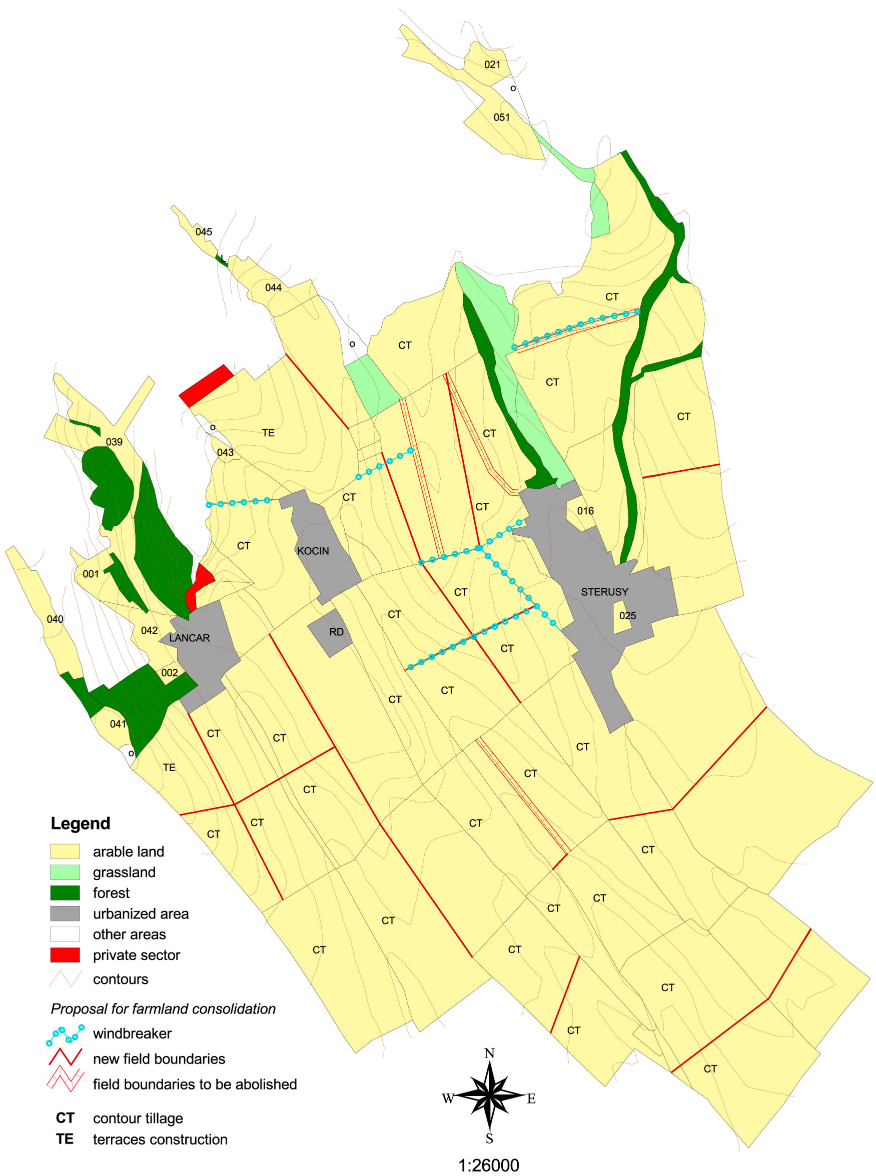


Fig. 1. Landform consolidation of the Cooperative Farm Kočín

We have selected 27 field block used for large-scale soil cultivation (arable land) and the average field size was 43.44 ha. After our analysis and revision of blocks of farmland, the proposed average size is 26.00 ha (see Fig. 1). Tab. 1 shows that original number of 27 fields was increased to 45. When comparing the proposed average field to the present state, the proposed average field size is smaller by 17.44 ha.

Landscape design, particularly field distribution; was constructed on traditionally arranged and utilized field blocks. Field shape have been made in respect of requirements for inevitable erosion control measures such as conservation tillage. Field shapes were adapted not only to natural conditions, but also to technological field availability. Within these requirements average field size and shape keep a geometrical regularity and whole.

The proposal of a new field arrangement is also connected with a new road system based on the already constructed communication net. The new road system provides access to the newly formed fields. The whole road net is constructed in a way, which supports anti-erosion influences. For instance furrows occurring along the roads are receptors and accumulators of rainfall.

## Erosion control proposals

Erosion control measures were proposed for every field block. We have tried to suggest measures which substantially reduce harmful sheet and gully water erosion, as well as wind erosion effects on soil cover. The following measures were proposed as the most suitable for the given climatic region:

- contour tillage,
- no-till minimum agrotechnics,
- conservation biocorridors (windshelters),
- terrace construction.

Contour tillage as one of the simplest erosion control measures is recommended very often. It is proposed for almost all field blocks in the studied farmland. It presents one of the most effective and economically suitable treatments, which prevent top layer runoff, as well as its accumulation on footslopes. When field size and sloping allow use of this technology, it can be combined with other contour technologies, particularly with no-till and minimum conservation agrotechnics. There are also some possibilities to use establishment of grassy belts along contours in combination with annually rotated crops, small terraces formations, etc.

Terracing is recommended in two field blocks, which are very strongly affected by water erosion. The main goal of terrace construction is substantial reduction of soil material runoff, the surface runoff from terraces is usually used to be negligible. Terrace width and length may be constructed with respect for parent material, soil texture, slope and relief shape, or this is unnecessary. Terrace edges can be fortified by grass or bush/tree rows. It is useful to secure functioning of the drainage system, the most suitable of which is a subsurface drainage system. Terraced areas should be used prevailingly for special cultures (vineyards, orchards). This erosion control proposal requires financial costs, but some special cultures can be profitable enough. Governmental subsidies can be a very acceptable impulse.

**Tab. 1. Farmland consolidation proposal of the Cooperative Farm PVOD Kočín**

| Block field number | Land use | Extent (ha) | Number of new fields | Erosion control proposal | Land use proposal |
|---|---|---|---|---|---|
| 001 | GR | 7 | 0 | 0 | GR |
| 002 | GR | 2 | 0 | 0 | GR |
| 003 | AR | 64 | 4 | TE(1), CT(3) | AR, VI |
| 004 | AR(PS) | 4 | 0 | 0 | AR(PS) |
| 005 | AR | 79 | 3 | CT(2) | AR |
| 006 | AR(PS) | 4 | 0 | 0 | AR(PS) |
| 007 | AR(PS) | 2 | 0 | 0 | AR(PS) |
| 008 | AR | 33 | 0 | CT, WB | AR |
| 009 | AR | 63 | 2 | TE(1) | AR,VI |
| 010 | AR | 28 | 2 | CT(1) | AR |
| 011 | AR | 35 | 2 | CT(1), WB | AR |
| 012 | AR | 71 | 4 | CT(4), WB | AR |
| 013 | AR | 13 | 0 | WB | AR |
| 014 | AR | 27 | 0 | CT | AR |
| 015 | GR | 7 | 0 | 0 | GR |
| 016 | PS | 2 | 0 | 0 | PS |
| 017 | AR | 18 | 0 | 0 | AR |
| 018 | AR | 34 | 0 | CT, WB | AR |
| 019 | AR | 46 | 0 | CT, WB | AR |
| 020 | AR | 14 | 0 | CT | AR |
| 021 | GR | 3 | 0 | 0 | GR |
| 022 | AR | 38 | 2 | 0 | AR |
| 023 | AR | 66 | 2 | CT(2) | AR |
| 024 | AR | 65 | 2 | CT(1) | AR |
| 025 | PS | 2 | 0 | 0 | PS |
| 026 | AR | 119 | 2 | 0 | AR |
| 027 | AR | 42 | 2 | CT(2) | AR |
| 028 | AR | 59 | 2 | CT(2) | AR |
| 029 | AR | 31 | 0 | CT | AR |
| 030 | AR | 22 | 0 | CT | AR |
| 031 | AR | 16 | 0 | CT | AR |
| 032 | AR | 76 | 2 | CT(1) | AR |
| 033 | AR | 41 | 0 | CT | AR |
| 034 | AR | 24 | 0 | CT | AR |
| 035 | AR | 33 | 0 | CT | AR |
| 036 | AR(PS) | 3 | 0 | 0 | AR(PS) |
| 037 | PS | 2 | 0 | 0 | PS |
| 038 | GR | 8 | 0 | 0 | GR |
| 039 | GR | 13 | 0 | 0 | GR |
| 040 | GR | 8 | 0 | 0 | GR |
| 041 | GR | 3 | 0 | 0 | GR |
| 042 | GR | 7 | 0 | 0 | GR |
| 043 | GR | 1 | 0 | 0 | GR |
| 044 | GR | 8 | 0 | 0 | GR |
| 045 | GR | 2 | 0 | 0 | GR |
| 046 | PS | 3 | 0 | 0 | PS |
| 047 | AR | 16 | 0 | CT | AR |
| 048 | GR | 2 | 0 | 0 | GR |
| 049 | GR | 3 | 0 | 0 | GR |
| 050 | GR | 2 | 0 | 0 | GR |
| 051 | GR | 13 | 0 | 0 | GR |

Explanations: Ar – arable land, GR – grassland, VI – vineyards and orchards, PS – private sector, CT – contour tillage, TE – terraces, WB – windshelters and green biocorridors. Number in brackets indicates number of fields recommended for erosion control measures.

In many areas of sloping terrain (convex forms) preservation green biocorridors were proposed, composed of several vegetation stages, or windshelters combined with tree-alleys. These belts of permanent vegetation are a very important sedimentation filter and very effective tool against soil mass losses. In the pilot area several such vegetation belts have been established, further belts are suggested for implementation.

Most fallows, which have anti-erosion significance by catching surplus runoff water are formed on concave relief forms. They can prevent gully and rill erosion. All fallows must be covered by vegetation and categorized as grassland or purpose green (in the sense of our legislation).

Areas which are extremely vulnerable to strong water erosion are suggested for the permanent grassland category. They are small fields of irregular shape, non-productive, extremely erodible areas, where vegetation cover is a significant tool to prevent soil erosion.

In our country there is no experience with alternation of grassy belts established along contours, therefore this erosion control system was proposed, because its although positive effects have been proved. According to several authors (Michalson et al. 1999, Thornes 1990, Schwertman et al. 1988) this way of soil conservation helps to minimize soil material loss at a tolerable level with minimum costs.

For every field block erosion control measures were proposed and new or changed proposals for land use were made (Fig. 1). The suggested measures may substantially mitigate harmful effects of water/wind erosion and ensure ecological stability of the area. Detailed measurement of soil erosion in this region has been started now, we have only first results.

## CONCLUSIONS

An erosion control system was proposed in harmony with natural conditions, on the basis of knowledge of the present erosion status and present state of agricultural land use. Whole land consolidation with design of new field shapes and size, a new road system and other erosion control measures have been proposed with the aim of securing ecological stability in conditions of intensive agriculture. This paper can be completed by erosion control crop rotation, but that is the topic of another study. The consolidation project was discussed with the authorities of the pilot region Kočín. It is assumed that implementation of our proposals will mitigate the effects of exceeded sheet water erosion and significantly contribute to land consolidation and soil fertility conservation. Some of our proposals have already been implemented.

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## PROTIERÓZNA OCHRANA V PODMIENKACH GEOMORFOLOGICKY ČLENITÉHO ÚZEMIA

Príspevok je orientovaný na problém usporiadania a konsolidácie územia v podmienkach veľkovýrobného poľnohospodárstva. Vychádzame z poznatkov získaných v priebehu formovania modelového podniku Poľnohospodárske výrobné a obchodné družstvo (PVOD) Kočín. Družstvo hospodári na pôdach hnedozemného charakteru, vytvorených na spraši a zvetralinách spodnej časti a podsvahových polôh Malých Karpát, prevažne hlinitého charakteru.

Zvlnený charakter krajiny naznačuje vysokú mieru zraniteľnosti pôdy zo strany eróznych procesov, najmä procesov vodnej erózie. Vo veľkej miere sa tu uplatňuje plošná aj ryhová erózia. Prakticky celé územie je poznačené eróznymi procesmi charakteru odnosu alebo sedimentácie. Svahovitosť pozemkov gravituje do dvoch kategórií: 3-7$^{o}$ a 7-12$^{o}$. Prvá kategória svahovitosti so sklonom menším ako 3$^{o}$ sa koncentruje na hrebeňové a údolné, podsvahové partie.

Klimatické podmienky sú charakterizované priemernou ročnou teplotou 9,2$^{o}$C a zrážkami, ktoré v dlhodobom priemere prevyšujú 600 mm ročne. Z toho viac ako 50 % spadne v priebehu vegetácie (apríl – september).

Celková plocha poľnohospodárskej pôdy obhospodarovanej PVOD Kočín je 1295 ha. Agrotechnika sa realizuje v rámci jednotlivých honov; ich celkový počet je 51 a priemerná veľkosť 25,4 ha s amplitúdou 1-119 ha.

Komplex pôdoochranných opatrení rešpektuje pôdne, prírodné a agrotechnické podmienky. Je rozdelený do štyroch skupín:

- vrstevnicová agrotechnika,
- bezorbová a minimálna agrotechnika,
- ochranné biokoridory (vetrolamy, živé ploty),
- terasovanie.

Vrstevnicová agrotechnika sa odporúča na všetkých svahových polohách so sklonom menším ako 9$^{o}$. Jej najväčšia pôdoochranná funkcia sa predpokladá na ornej pôde v mimovegetačnom období (október – apríl). Erózny odnos sa redukuje až o 50 %.

Pôdoochranné technológie – bezorbová a minimálna – sa odporúčajú na orné pôdy so svahovitosťou 3-12$^{o}$. Je to najúčinnejšia forma protieróznej ochrany pôdy. Je však závislá na relatívne drahej technike (bezorbové sejačky a aplikátory hnojív a prípravkov chemickej ochrany rastlín). Nákup týchto strojov sa realizuje postupne, v závislosti na finančnej sile družstva.

Ochranné biokoridory sa budujú postupne. Ich momentálna celková dĺžka je 5000 m a predpokladá sa ich zväčšenie na celkovú dĺžku 16 400 m. Cieľom tohto opatrenia je ochrana pred veternou (a čiastočne i vodnou) eróziou pri súčasnej biologizácii a ekologizácii a diverzifikácii krajiny. Budujú sa v zmysle zásady čiastočnej obnovy pôvodnej trvalej vegetácie na medziach a hospodárskeho úžitku z ovocných stromov a zabranej plochy pôdy.

Terasovanie je aktuálne vo vinohrade, ktorý sa tiež postupne rozširuje. Tu je predpoklad návratnosti vynaložených prostriedkov v dohľadnej dobe.