An Erosion Control System for Sustainable Land Use on Hilly Relief in Lithuania

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1. Introduction

Soil erosion is a hazard associated with ecology and especially with agriculture. It is important for long-term effects on soil productivity and sustainable land use. Erosion control is now a necessity in almost every country of the world under every type of land use (Morgan, 1995). The parent rock, soil texture, relief, rainfall, velocity of wind and plant cover are natural factors influencing the rates of erosion (Morgan, 1995; Jozefaciuk and Jozefaciuk, 1996; Zachar, 1982). Tillage creates favourable conditions for water and wind erosion and was assumed to be the primary cause of erosion (Jankauskas, 1994; Lobb et al., 1995).

About 52% of Lithuania has a hilly-rolling relief, were the soil is erodible (Kudaba, 1983). We have investigated the soil erosion processes in the Zhemaichiai upland (Western Lithuania). The last glacier (about 12 thousand years ago) left a thin layer of erodible glacial clay loam moraine on the old basis. There are long moderately and strongly sloping hills in the central part or short gently sloping and densely grouped hills in the outskirts of the upland. The annual precipitation is 800-858 mm in the central part of the Zhemaichiai upland and 750-800 mm in the lower parts of it.
The erosion-resisting capability of perennial grasses and winter grains (Morgan, 1995; Jankauskas, 1996; United States Environmental Protection Agency, 1996), as well as reduced tillage systems (Arshad et al., 1997; Schumacher et al., 1997) allow opportunity to design field experiments and to develop an erosion control system for the erodible soils of Lithuania.

2. Methods

The erosion control system for sustainable land use on hilly-rolling relief in Lithuania was first prepared on the basis of experiments carried out by the author in Vezhaichiai branch and Kaltinenai Research Station of the Agricultural Institute of Lithuania (Jankauskas, 1994). This system was supplemented by new research data of the author (Jankauskas, 1996) and other researchers of Kaltinenai Research Station (Arlauskas and Feiza, 1996; Feiziene, 1996; Jankauskas and Jankauskiene, 1996; Norgailiene and Zableckiene, 1994). Most experimental results were obtained by field experiments on the slopes, hill tops and footslopes of hilly-rolling Zhemaichiai upland (approximately 55^0 34’ N and $22^0$29’ E). The prevailing soils were Dystric and Gleyic Podzoluvisols, loamy sand or clay loam with primary excessive acidity (pH_{KCl} to 5.5), low amounts of mobile P_2O_5 (50-100 mg kg^{-1}) and medium or higher than medium mobile K_2O (100-200 mg kg^{-1}).

3. Results

The arable soils on hilly-rolling relief are eroded by tillage operations, water and wind. The natural soil fertility on slightly, moderately and severely eroded slopes has decreased by 21.7, 39.7 and 62.4 per cent, respectively, due to the deterioration of physical and chemical properties. The dry bulk density and percentage of clay-silt and clay fractions increased, the total porosity and water field capacity decreased. Strong acidity of E, EB and B1 horizons and increased acidity throughout the soil profile of eroded Dystric Podzoluvisols are characteristic features (Jankauskas, 1994).

Table 1. Erosion-preventive grouping of erodible terrain and erosion-resisting measures

Groups	Texture of soil* and gradients of slopes		Type of land use	Requirements	Recommended erosion-resisting measures
	S, LS, G	L, C			
I	Over 10^0	Over 15^0	Woods	To pick out slopes over 10^0 and 15^0. Slopes over 10^0 of heavy texture and over 5^0 of light texture are unsuitable for land reclamation.	To plant trees or shrubs, to tend carefully perennial grasses.
II	$7\text{-}10^0$	$10\text{-}15^0$	Grass-land	Along with the indicated slopes to annex the inconvenient for tillage, more plain arable plots and to establish the pasture or grassland.	To plant perennial grasses for long-term use. To renovate it by mixture of another composition. Cover crop must be annual grasses.
III	$5\text{-}7^0$	$7\text{-}10^0$	Arable land or grass-land	Similar to IInd group, only indicated plot must be of suitable form for tillage.	To put into practice the erosion-preventive grain-grass crop rotation. To apply erosion-preventive tillage means.
IV	$2\text{-}5^0$	$3\text{-}7^0$	Arable land	Similar to IIIrd group, only 10% of light soil slopes up to 7^0 can be annexed.	To put into practice the erosion-preventive grass-grain crop rotation. To apply erosion-preventive tillage means. To avoid growing of tillage crops and flax.
V	Up to 2^0	Up to 3^0	Arable land	Plain, suitable for tillage plots, these remained after forming of I-IV groups.	To put into practice intensive field crop rotation. On the slopes of $2\text{-}3^0$ to apply erosion-preventive tillage means.

*** S - sand, LS - loamy sand, G - gravel, L - loam, C - clay.**

The outlines of our suggested erosion control system is presented in table 1. The territory of farmland on hilly-rolling relief should be divided into 5 groups. The Ist group covers highly erodible soils, i.e. slopes over 10^0 having sandy, loamy sand or gravel texture (light soils) and slopes over 15^0 having loamy or clay texture (heavy soils). We suggest planting trees on such slopes. The growing of long-term perennial grasses was recommended on the light soil slopes of $7\text{-}10^0$ and heavy soil slopes of $10\text{-}15^0$ and on surrounding soil unsuitable for any other exploitation (IInd group). We suggested erosion-preventive grass-grain crop rotation, including 50-80% of perennial grasses for soils of the IIIrd group, i.e. on slopes of $5\text{-}7^0$ with light soils and on slopes of $7\text{-}10^0$ with heavy soils. The above mentioned slopes should be arranged into a plot of land suitable for tillage. The IVth group covers slopes of $2\text{-}5^0$ with light soils and $3\text{-}7^0$ with heavy soils and represents utilization of erosion-preventive grain-grass crop rotations including 33-50% of perennial grasses. When growing grain crops, it is important to use erosion-preventive tillage and fertilization on undulating and rolling relief. The Vth group covers the remaining fields on flat and gently undulating relief. The common field crop rotation can be used on these soils, however on slopes of $2\text{-}3^0$ erosion-preventive tillage is suggested.

The thriftily growing perennial grasses provide full protection from soil erosion even on the slopes of $10\text{-}15^0$. Permanent legume-grass mixtures were studied first on Kaltinenai

Research Station. Grass mixtures with a high percentage (90%) of lucerne were more suitable for hilly pastures on soils suitable for growing lucerne. The annual average yield of dry matter was 6.12 t ha^{-1} or 0.92 t ha^{-1} of digestible protein. Later investigations proved that soils of the Zhemaichiai upland are not very suitable for growing lucerne due to the excessive acidity of soils and waterlogged subsoil. Therefore it was necessary to establish which long-term perennial grasses are more suitably for these soils. The field experiments were successful. Grass mixtures of high fertility for early, medium and late hay making or grazing were established. The annual average productivity of the most fertile hay meadow mixture during a 6-year period was 7.86-9.15 t ha^{-1} of dry matter. The productivity of the pastureland was 5.56-7.07 t ha^{-1}. The productivity of these grass mixtures did not decrease during a 6-year period, indicating that the duration of these grass mixtures can be longer (Norgailiene and Zableckiene, 1993). These long-term perennial grass mixtures can be used for grasslands on areas within the IInd group of erodible terrain.

Erosion-preventive six-course crop rotations have been investigated at the Kaltinenai Research Station since 1983. The erosion-preventive grain-grass crop rotation contained 67% of grains and 33% of perennial grasses. The erosion-preventive grass-grain crop rotation contained 33% grains and 67% perennial grasses. Tillage crops and flax are not grown in erosion-preventive crop rotations. According to the average annual research data of 12 years of field experiments (1983-1994), the heavy losses of soil due to water erosion on slopes of 2-5^0, 5-10^0 and 10-14^0 were determined as follows: 3.5-10.8 m^3 ha^{-1} under winter rye, 11.7-38.0 m^3 ha^{-1} under spring barley and 28.8-118.6 m^3 ha^{-1} under potatoes. The perennial grasses completely stopped soil erosion. The losses of soil under erosion-preventive grass-grain crop rotations decreased by 76.8-80.8% in comparison with the field crop rotation, while on the grain-grass crop rotation it decreased by 21.5-24.4%. The amount of metabolizable energy accumulated in anti-erosion grass-grain crop rotations was 88.9-103.4 GJ ha^{-1} or 14.1-32.7% higher than in the field crop rotation and 11.8-27.7% higher than in the grain-grass crop rotation (Jankauskas and Jankauskiene, 1996). The above research data enabled to design and to recommend erosion-preventive crop rotations (Table 2). These erosion-preventive crop rotations can be used on the plots mentioned under the IIIrd and IVth groups of erodible terrain (Table 1).

According to our investigations, even grass-grain crop rotations could not completely stop soil erosion. The annual rates of soil loss by water erosion were 9.4-9.7 t ha^{-1} on the slope of 10-14^0, 6.0-6.2 t ha^{-1} on the slope of 5-10^0, and 2.8-2.9 t ha^{-1} on the slope of 2-5^0 gradient.

Therefore we recommended grassing of slopes over 10^0 and using erosion-prevention tillage and fertilising-liming on the slopes of 2-10^0 in addition to erosion-preventive crop rotations.

In the autumn soil tillage system, deep soil chisel tillage can be used instead of deep mouldboard ploughing, and spraying the stubble with herbicide ‘utal’ can be used instead of stubbling and deep ploughing. Rates of soil erosion were reduced by the above method by 1.6 and 8.9 times, while productivity remained at the same level (Arlauskas and Feiza, 1996). Differentiation of nitrogen fertiliser rates on various parts of the hilly-rolling upland (Feiziene, 1996) and combination of fertilising and liming of eroded acid soils (Jankauskas, 1996) are important parts of the erosion control system, too.

Table 2. The erosion-preventive crop rotations for fields differing in hill gradients

Biggest slope gradient	Per cent of grasses in a crop rotation	Composition of crop rotation
7-10^0	80.0	I. 1 - winter grains or barley, 2-5 - perennial grasses.
	71.5	II. 1 – winter grains, 2 - barley, 3-7 - perennial grasses.
	67.0	III. 1 – winter grains, 2 - barley, 3-6 perennial grasses.
	62.5	IV. 1-2 winter grains, 3 - barley, 4-8 - perennial grasses.
	62.5	V. 1 – winter grains, 2 - spring grains, 3 - barley, 4-8 - perennial grasses.
	60.0	VI. 1 – winter grains, 2 - barley, 3-5 - perennial grasses.
5-7^0	57.0	VII. 1-2 – winter grains, 3 - barley, 4-7 - perennial grasses.
	57.0	VIII. 1 – winter grains, 2 - spring grains, 3 - barley, 4-7 - perennial grasses.
	50.0	IX. 1-2 – winter grains, 3 - barley, 4-6 - perennial grasses.
	50.0	X. 1 – winter grains, 2 - cereal grains with leguminous, 3 - barley, 4-6 - perennial grasses.
	43.0	XI. 1 – winter grains, 2 - cereal grains with leguminous, 3 - winter grains, 4 - barley, 5-7 - perennial grasses.
	43.0	XII. 1 – winter grains, 2 - cereal grains with leguminous, 3 - spring grains, 4 - barley, 5-7 - perennial grasses.
	40.0	XIII. 1 – winter grains, 2 - barley or their mixture with leguminous, 3 - barley, 4-5 - perennial grasses.
2-5^0	37.5	XIV. 1 – winter grains, 2 - spring grains, 3 - cereal grains with leguminous, 4 - winter grains, 5 - barley, 6-8 -perennial grasses.
	37.5	XV. 1 – winter grains, 2 – spring grains, 3 - cereal grains with leguminous, 4 - spring grains, 5 - barley, 6-8 -perennial grasses.
	33.3	XVI. 1 – winter grains, 2 – spring grains, 3 - cereal grains with leguminous, 4 - barley, 5-6 -perennial grasses.
	33.3	XVII. 1-2 – winter grains, 3 - cereal grains with leguminous, 4 - barley, 5-6 - perennial grasses.

4. Conclusions

- The main measure of our proposed erosion cropping system is selection of agrophytoceses (long-term perennial grasses, erosion preventive crop rotations) with a high erosion resisting capability. Only erosion preventive grass-grain crop rotations decreased losses of soil due to water erosion on slopes of 2-5^0 and 5-10^0 by 76.8-80.8% as compared with the field crop rotation.
- Spraying with herbicide utal and deep chiseling instead of mechanical stubbling and deep mouldboard ploughing or only spraying with utal without the primary soil tillage can be used on the eroded slopes. It enabled to additionally lower the loss of soil under grain crops in erosion-preventive crop rotations.
- The erosion-resisting importance of fertilizing-liming depends on the luxuriance of the vegetation that determines the capability of plants to protect the soil surface against raindrops striking and overland flow. Therefore the most eroded slopes and tops of hills must be selectively fertilized using higher rates of mineral nitrogenous and organic fertilizers. The rates of applied fertilizers can be lower on the footslopes and between hills.

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