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The Potential Soil Erosion Risk in the Wine-Growing Regions of Hesse

Viticulture has undergone dramatic changes in the last century. The introduction of grafting onto Phylloxera-resistant rootstocks and widespread mechanization, specialization and intensification has had extensive effects on viticulture. The transition towards mechanized tillage has even reached the steep slopes, replacing the traditional work positioning system using rope and tackle. The direct access of these sites with motorized equipment creates tracks of compacted soil or plow horizons, which prevent the infiltration of rainwater and promote surface runoff. Land consolidation has resulted in larger vineyards, causing the volume of surface runoff and flow speed to increase – thus intensifying the risk of erosion. Practical erosion control using suitable methods is a vital part of steep-slope vineyard management.

This problem has been the topic of many studies since the revival and intensification of viticulture in the 1950s (GEGENWART 1952, HERMANN 1965, HORNEY 1969, 1974, KURON et al. 1956, KURON & JUNG 1961, JUNG & BRECHTEL 1980, RUPPERT 1952, SCHMITT 1952, 1954, 1955). These indicate that erosivity (precipitation) as well as erodibility (soil susceptibility) factors are decisive parameters for evaluating soil erosion. KURON et al. (1956) developed a mapping method to determine the erosion risk during land consolidation procedures and provide the basis for soil conservation measures (RICHTSCHEID 1988). The survey results were published in a "Risk Map - Soil Erosion by Water", which covered the agriculturally used land in Hesse. This risk assessment is used for agricultural structure planning since it also recommends specific control measures and, where necessary, land use restrictions for each erosion class.

A modified approach of soil erosion risk assessment was specifically developed for the wine growing regions of Hesse (EMDE 1992). The evaluation model is mainly based on two key parameters: type and volume of precipitation, and susceptibility of the soil type to erosion. Both factors are included in the "Empirical Soil Loss Model" (WISCHMEIER & SMITH 1978) – the basic model for predicting potential soil erosion risk in the wine-growing regions of Hesse.

Soil factors

Any assessment of soil erodibility must take into account organic matter and carbonate content as well as topsoil aggregate stability. However, one of the most important parameters is soil texture, from which it is possible to deduce hydraulic conductivity. Soil erodibility can be calculated using these parameters (SCHWERTMANN et al. 1987). Since it was not always possible to deduce the coarse fraction of the soil from the raw data, the soil type was defined according to the specific substrate. This produces a more reliable interpretation of soil type than the ecological soil groups

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or soil evaluation data. Since a digital elevation model was not available at the time of this study, it was necessary to use the survey data collected for the „Risk Map - Soil Erosion by Water“. The slope classes introduced in this survey were also used for the present revised edition:

<2 %
2 – <6 %
6 –<12 %
12 –<18 %
18 –<24 %
>24 %

Additional parameters such as length of slope and degree of cover were omitted because of the lack of data.

Results

The erodibility index describes the susceptibility of soils to erosion. The index is 1 for the most susceptible soils. Each soil index expresses the relative deviation from the maximum value. Each ecological soil group can be associated with a characteristic erodibility index, even if the actual values tend to vary considerably within the soil units. The following results were obtained for the Rheingau:

Soil group II	0.3 – < 0.4
Soil group III	0.4 – < 0.5
Soil group IV	0.3 – < 0.4
Soil group V	0.4 – < 0.6
Soil group VII	0.2 – < 0.3

Because of the scarcity of the soil groups IV, VI and VII in the Bergstrasse Region, it was not possible to determine erodibility indices for these soils:

Soil group I	around 0.2
Soil group II	0.3 – <0.5
Soil group III	0.4 – <0.5
Soil group V	<0.6

The disparity between both wine growing regions, especially concerning soil group II, are due to regional differences in soil distribution patterns within this soil group. The high erodibility indices obtained for soil group V is a result of the extremely erodible silt content in the loess-dominated calcaric regosols.

Climatic factors

High intensity rainfall events, when precipitation rates exceed 10 mm in 6 hours, are categorized as highly erosive. Lower precipitation rates are also considered to be highly erosive when at least 5 mm rain falls within 30 minutes. Such detailed information can only be provided by climate stations with rainfall gauges. The climate of wine growing regions of Hesse has been monitored by the stations in Geisenheim for over 30 years, and Bensheim and Darmstadt for over 10 years.

Results

The monthly distribution of erosive high intensity rainfall events (Table 1) reveals a similar pattern for all climate stations. These events are restricted to the summer half-year, especially in July and August, which corresponds to the frequency of summer thunderstorms.

However, a detailed comparison of the data shows that there are some differences between the stations. The recorded rainfall intensity is twice as high in Darmstadt/Heppenheim than in Geisenheim.

Tab. 1. Mean monthly erosive rain measured at the stations Geisenheim, Heppenheim and Darmstadt as well as annual average

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ø
Geisenheim (1961–1990, 260 erosive rain events, Ø 8.7 rain/April–October)	0 0	0 0	0 0	0.5 0.5	4.1 4.1	7.8 10.0*	9.3 12.5*	7.9 10.2*	4.0 4.0	1.5 1.5	0 00	0	35.1 42.7*
Geisenheim (1970–1979, 70 erosive rain events, Ø 7.0 rain/April–October)	0	0	0	0.9	4.6	5.9	13.3	6.5 13.6*	1.7	0.8	0	0	33.7 40.8*
Heppenheim (1983–1994, without 91/92; 127 erosive rain events, Ø 12.7 rain/April–October)	0	0	0	1.3	9.5	28.0	11.3	14.4	8.5	2.0	0	0	75.0
Darmstadt (1970–1979, 161 erosive rain events, Ø 16.1 rain/January–December)	0.1	0.9	0.8	1.9	8.8	9.3	21.6	14.6	4.0	2.3	4.1	1.8	70.2

* including extreme erosive rain events

Classification of the potential erosion risk

The potential erosion map of the wine-growing regions of Hesse is based on an evaluation of rainfall erosivity and soil erodibility. The importance of these factors was ranked as follows:

- climatic conditions, frequency and intensity of heavy rainfall events
- soil erodibility
- slope gradient

In this survey, precipitation characteristics (intensity, chronological distribution and frequency of heavy rainfall events) were considered to be the most important variable affecting erosion.

By combining soil and climate variables it was possible to differentiate the vineyard soils into four classes (A to D in Table 2) according to their susceptibility to erosion. Group A (very high erodibility) includes the silty calcaric regosls developed on loess which have already been shown to be highly erodible during intense rainfall events. The least erodible soils are those containing large amounts of stones and rubble (Group D: low erodibility). A high degree of stoniness protects the soil from erosion. Locations with stony soils are upgraded in terms of potential erodibility.

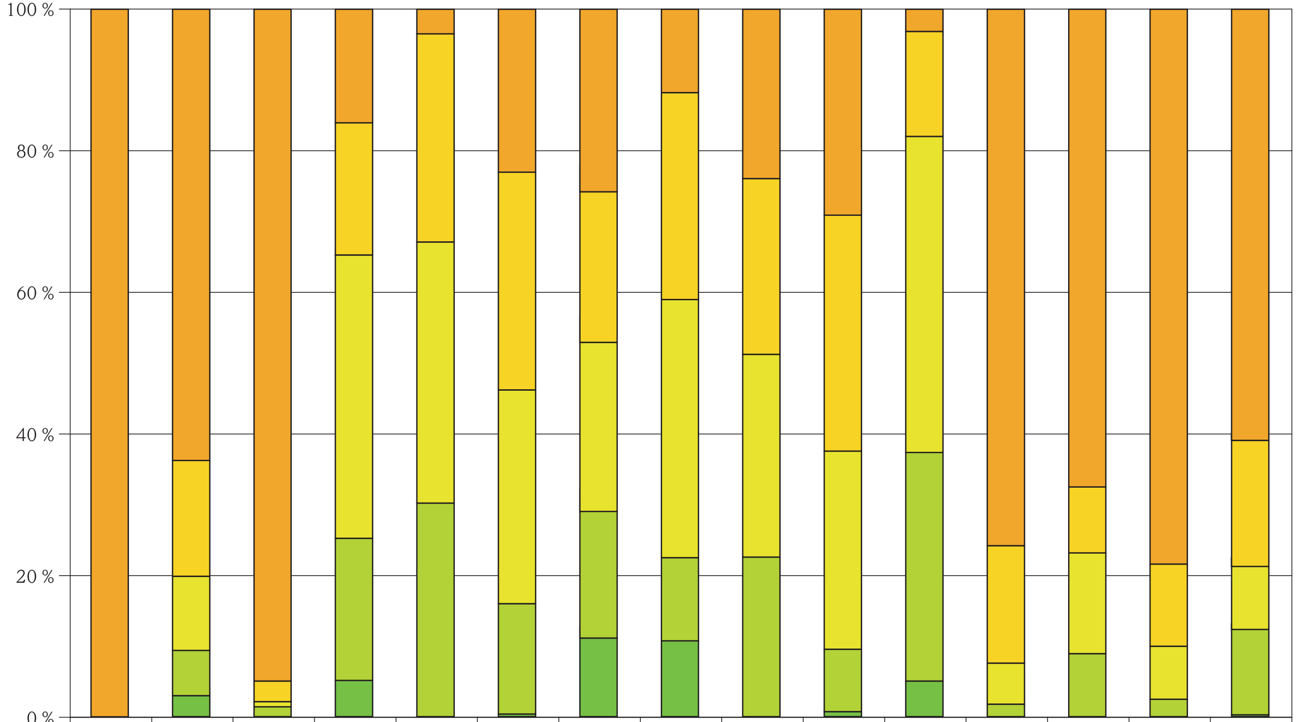
Slope gradient has a profound effect on the erosion risk class. However, the consequences depend on the specific soil. While the erosion risk for calcaric regosols from loess and cambisols from dystrophic sand deposits substrates is very high (Group A) for slope gradients exceeding 12 %, most other soils only attain this class on inclines steeper than 18 %. For very coarse soils, the gradient must exceed 24 % before the erosion risk is very high.

The regional analysis reveals that the potential erosion risk is exceptionally high for the Bergstrasse wine growing area. This region is characterized by frequent intense rainfall events and high proportion of very erodible soils consisting of loess and from dystrophic sand deposits. The erosion risk in the Middle Rhine Valley is also very high as a consequence of the extremely intense relief, which supersedes all other fac-

Tab. 2. Levels of erodibility (E) of soils due to water for land use type viticulture

Slope gradient [%]	**Group A**		**Group B**		**Group C**		**Group D**	
	a)Calcaric regols from loess substrate b)dystrophic cambisols from loess substrate		a) Haplic luvisols from loess substrate over loess b) Haplic luvisols from shallow loess substrate over other type of rock c) Eutric cambisols from marine sand substrate		a) Transitional types from Haplic luvisols b) Calcaric regosols on marl substrate c) Fluvisols, Gleysols d) Soil types with ≤ 40 % stoniness (in topsoil)		a)Eutric cambisols or Haplic luvisols on substrate with low loess content over different types of rock debris b) Eutric cambisols or Haplic luvisols from slope deposits substrate c) Soil types with ≥40 % stoniness (in topsoil)	
	Erodibility very high		Erodibility high		Erodibility moderate		Erodibility low	
0 ≤ 2	low to moderate	E 2	low to moderate	E 3	low	E 2	very low	E 1
2 ≤ 6	moderate to elevated	E 4	low to moderate	E 3	low to moderate	E 3	low	E 2
6 ≤ 12	elevated to high	E 5	moderate to elevated	E 4	moderate to elevated	E 4	low to moderate	E 3
12 ≤ 18	very high	E 6	elevated to high	E 5	elevated to high	E 5	moderate to elevated	E 4
18 ≤ 24	very high	E 6	very high	E 6	very high	E 6	elevated to high	E 5
> 24	very high	E 6	very high	E 6	very high	E 6	very high	E 6

tors. The pattern is somewhat differentiated in the Rheingau. The erodibility of the soils on the steep south and south-west facing slopes is very high, despite the presence of Tertiary clays and Marls, which are less susceptible than loess. Locations covered by coarse soils on debris flows are less susceptible to erosion since the kinetic energy of the rain is effectively dissipated by the stones. A similar situation also characterizes the Maingau. Figure 1 shows a statistical overview of the regional erosion risks.



	no collective vineyards	Burgweg	Steil	Ernte-bringer	Gottesthal	Mehrhölz-chen	Deutels-berg	Honigberg	Heiligen-stock	Stein-mächer	Daubhaus	Rott	Wolfs-magen	Schlossberg	no collective vineyards Gross-Umstadt
		Rheingau									Maingau	Hess. Bergstrasse			
very high	4,3	499,7	91,4	113,9	10,2	80,7	81,4	29,9	53,7	211,0	12,8	131,6	110,6	268,2	70,1
elevated to high		128,2	2,8	132,6	86,0	107,8	67,4	74,2	55,7	241,8	60,7	28,7	15,1	39,8	20,5
moderate to elevated		82,2	0,7	284,1	108,0	105,9	75,7	92,5	64,2	203,2	182,9	9,9	23,2	25,6	10,2
low to moderate		50,1	1,3	142,6	88,3	54,6	56,5	29,9	50,6	63,9	132,3	3,2	14,4	8,5	14,1
low		23,2		36,2		1,3	35,7	27,1		5,2	20,6				0,3

Fig. 1. Spatial distribution of erodibility classes in collective vineyards (proportion in the collective vineyard– graph; area in ha – table).

Tab. 3. Recommendes soil conservation practices in viticulture

E 1:	No special measures required above normal viticultural practice
E 2:	cover crops in alternate alleys, clean tillage underneath vines
E 3:	cover crops in alternate alleys, cover soil underneath vines during vegetation period, mulch clean alley, or plant entire area with cover-crops if water supply is adequate
E 4:	cover crops in alternate alleys, cover soil underneath vines during vegetation period, mulch clean alley, or plant entire area with cover-crops if water supply is adequate
E 5:	plant vineyard with perennial cover crops, clean-tillage underneath vines during vegetation period, or cover crops in alternate alleys, or clean tillage underneath vines during vegetation period and mulch application in alternate alleys
E 6:	Sites with adequate water supply: • plant vineyard with perennial cover crops, Sites with inadequate water supply: • apply mulch over entire vineyard area • plant cover crops in alternate alleys, cover soil beneath vines during vegetation period, apply mulch to other alleys; Create plot lengths less than about 60 m during land consolidation

Recommended soil conservation practices in viticulture

In the own interest of the winegrowers and to protect soil and environment, traditional vineyard soil management practices have always included specific measures for preventing soil loss or reducing erosion to a necessary minimum. Table 3 summarizes the various available management practices, soil covers and tilling techniques recommended for achieving this objective.

Planting perennial cover crops between rows and on access routes is the optimal solution for reducing sheet erosion. However, competition between grass and vines can lead to water stress in dry years, which may have an effect on wine quality. This is why cover crop management systems must take into account soil water conditions. All highly erodible soils assigned to erosion risk classes E 5 and E 6 require sustainable conservation measures to prevent soil loss. These productive locations are often found on steep slopes (gradient >18 %). The soils are often very shallow and coarse because of the steep terrain. As a result, the soil moisture regime is unstable and characterized by a low water retention capacity. Although perennial cover-cropping would alleviate soil loss, the vine would probably suffer from water stress. Alternative methods are used to reduce the erosion risk. These include cover-cropping only every second alley or using suitable materials to cover the bare soil in the alleys. However, outside the vegetation period of the vine, each of these locations will benefit from a natural or planted winter cover. The optimum solution for these sensitive locations would be a combination of perennial cover-crops and drip irrigation of the vines, which would prevent water stress on the one hand and soil loss on the other.

In addition to the different cover-cropping systems, soil loss can also be reduced by using cover materials. While straw is rarely used (fire hazard), compost is a common cover material not only because of the fertilizing effect. However, precisely this effect is the limiting factor as it is associated with elevated nitrogen inputs. Since nitrate inputs are restricted in viticulture (Zimmer 2004) alternative materials are more suitable for covering the soil. The most popular material used in viticulture is bark mulch which has a negligible fertilizing effect due to the high C:N ratio.

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