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THOMAS ZIMMER*

The Map of Plant Available Water Capacity

One of the most important soil properties for viticulture is the capacity of the soil for storing water that is available to the vines when required. This plant-available soil water is characterized by the available water capacity (AWC) of the soil. The AWC is also an important parameter for defining ecological soil groups, assessing nitrate leaching potential and for planning soil amelioration measures.

AWC is defined as the water retained in the soil against the force of gravity that is readily available to plants. The upper limit of plant available water is known as the field capacity of the soil. This is measured by means of the pressure (cm water column) required to drain the relevant pores of the soil. The energy with which water is held in a soil is expressed as the logarithm of the height in centimetres of a column of water (pF-value). The plant available water capacity is given by the difference of soil water content at pF 4.2 and that at pF 1.8. Water held in fine pores at tensions greater than pF 4.2 (pressure > 15.000 cm water column) is unavailable to plants. This value is known as the wilting point. Water is not stored in the soil above pF 1.8 (pressure < 60 cm water column).

The method

In order to create an AWC map, various soil physical and chemical parameters were determined for 264 horizons. The upper and lower range limits of these parameters are shown in Table 1. Experience shows that there is a close correlation between pore size distribution and the particle size distribution curve. This is confirmed by the regression analyses shown in Figs 1 and 2 between pore volume at pF 4.2 and clay content (Fig. 1) and pore volume at pF 1.8 and sand content (Fig. 2). This close correlation means that the volume of water at pF 4.2 and 1.8 can be inferred directly from soil texture determinations (TIETJE & HENNINGS 1993, TIEDJE & TAPKENHINRICHS 1993, ZIMMER 1996, 1997).

Taking advantage of this correlation, it was possible to include the previously determined particle size distribution results for an additional 688 horizons.

Tab. 1. Minimum and maximum values of the analyzed soil parameters (only cylinder samples)

	Coarse fraction	Sand	Silt	Clay	Humus	Density	pF 1.8	pF 2.5	pF 4.2
Min.	0.0	3.7	9.8	5.0	0.0	1.19	11.1	7.6	2.2
Max.	54.4	85.2	78.9	66.2	6.5	1.79	49.3	44.9	30.4

* Dr. T. Zimmer, Ringstr. 42, D-63303 Dreieich

The calculation is based on the following formulae:

$$pF4.2 = 1.3716 + 0.4944 \times \text{clay (\% by wt.)}$$

$$pF1.8 = 31.481 – 0.144 \times \text{stoniness (\% by wt.)} – 0.173 \times \text{sand (\% by wt.)} + 0.18 \times \text{clay (\% by wt.)}$$

The following example illustrates the calculation procedure:

A cambisol on sandy terrace deposits is 100 cm deep consists of 5 % by wt. stoniness, 85 % by wt. sand and 5 % by wt. clay. Using the above formulae, the calculated water content at pF 4.2 is 3.8 % by vol. and 16.9 % by vol. at pF 1.8. The difference between these values is the available water content, in this case 13.1 (= 131 mm) for 1 m3 soil.

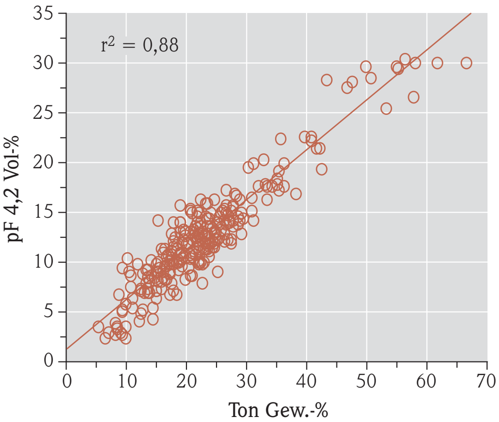


Fig. 1. Correlation between pF-value 4,2 and clay content.

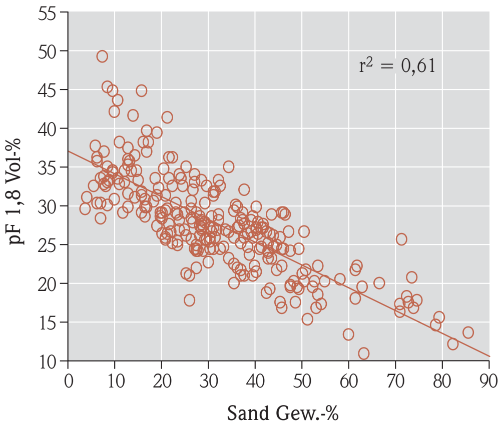


Fig. 2. Correlation between pF-value 1,8 and sand content.

The AWC-classes

All estimations of AWC are based on information presented in the original site survey maps and the soil profiles described in the soil survey maps of Hesse (Zakosek 1967b, Zakosek & Stöhr 1966). Any estimation of AWC must be preceded by establishing the reference soil depth. In this case, this involved determining the effective rooting depth before calculating AWC.

Class capacity	Water storage [mm]	AWC-class
I	low	< 100
II	low to intermediate	100–125
III	intermediate	126–150
IV	intermediate to good	151–175
V	good	176–200
VI	excellent	> 200
VII	stagnosols and fluvisols	

The following AWC-classes were defined:

Semi-terrestric, groundwater and floodwater influenced soils such as stagnosols and fluvisols were grouped into a single class. Their water budget is mainly determined by groundwater levels and much of the water taken up by plants is replenished by capillary rise in the vadose zone.

These AWC estimates also take into account the upper regions of the subsoil. This is necessary, because the perennial vine is capable of rooting to depths beyond 1 m, if subsoil properties do not restrict penetration. Studies by ZEPP (1988) and ZIMMER (1997) confirm that vines extract measurable amounts of water from depths beyond 1 m (Fig. 3). Because the vines benefit from this additional source of water all locations where the subsoil water storage capacity exceeds 12.5 % by vol. of the AWC were raised by one AWC-class. Those locations where 25 % by vol. of the AWC is stored in the subsoil were rated two classes higher. The classification of waterlogged soils posed more of a problem.

The appraisal of the area distribution of AWC-classes (Fig. 1) indicates that the greatest part, approx. 40 %, of the viticultural area in Hesse is categorized as Class VI (excellent). The proportion of Class II (100–125 mm) to V (175–200 mm) locations decreases from about 16 % to 10 % of the area under wine cultivation. Only about 6 % of the area is covered by the extremely unfavourable AWC class I. Gleyols and fluvisols only play a minor role, covering about 2.5 % of the area.

Class I (< 100 mm):

This class unites all very shallow soils with a high proportion of stoniness and very high sand contents. Even the subsoil of those soils not formed on solid rock will have a very coarse texture without any significant capacity for storing water. These soils are found in their natural positions on steep slopes and frequently on locations with a high erosion potential. Class I soils are usually limited to small patches in exposed steep terrain. Some larger areas covered by these soils can be found between Rüdesheim and Assmannshausen. These soils cover about 70 ha or 23 % of the collective vineyard Burgweg, west of

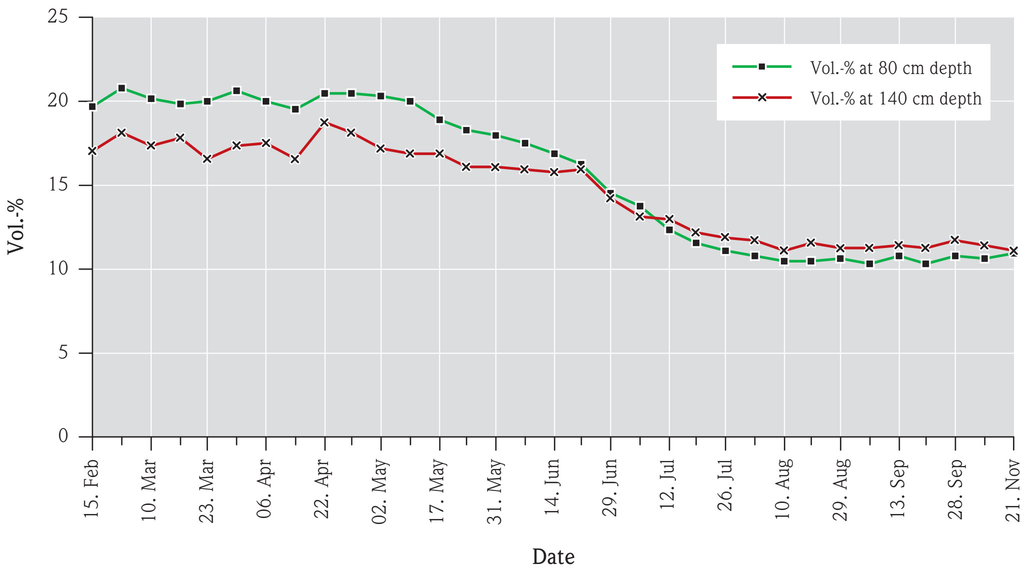
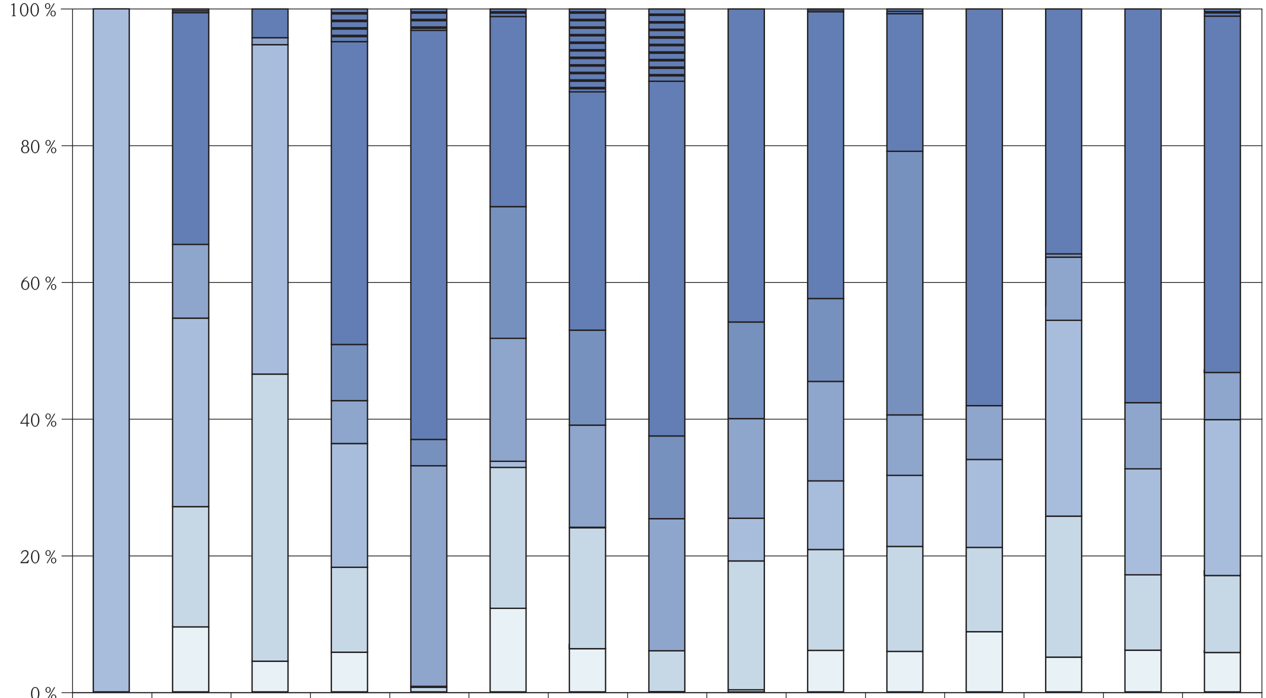


Fig. 3. Annual development (1994) of soil moisture.



	no collective vineyards	Burgweg	Steil	Ernte-bringer	Gottesthal	Mehrhölz-chen	Deutels-berg	Honigberg	Heiligen-stock	Stein-mächer	Daubhaus	Rott	Wolfs-magen	Schlossberg	no collect. vineyards
		Rheingau									Maingau	Hess. Bergstrasse			Gross-Umstadt
Stagnosols and fluvisols		3,9		35,2	9,1	3,9	36,3	26,9		3,0	2,9				1,1
> 200 mm		250,8	3,9	325,5	174,1	97,7	112,4	131,7	102,8	304,4	85,4	100,8	58,6	197,3	60,3
176 –200 mm				60,3	11,2	67,6	44,1	30,7	31,7	88,0	163,6		0,7		
151 –175 mm		79,6	0,9	46,2	93,9	63,2	47,6	49,1	32,7	105,4	37,5	13,6	15,1	33,1	8,1
126 –150 mm	4,3	204,0	44,6	133,0	0,5	3,1			14,0	72,8	44,1	22,4	46,7	53,1	26,3
100 –125 mm		130,0	38,9	91,3	1,9	72,4	56,5	15,2	42,3	107,2	65,2	21,3	33,7	37,8	12,8
< 100 mm		70,3	4,2	42,5		42,9	21,0	0,1	0,7	43,9	25,0	15,4	8,3	20,9	6,7

Fig. 4. Area distribution of available water capacity classes in collective vineyards (proportion in collective vineyards– graph; area in ha –table).

Rüdesheim. They also cover about 40 ha of each of the collective vineyards Erntebringer, Mehrhölzchen and Steinmächer (Fig. 4). The congruency with the ecological soil class I is very high since both are defined by similar parameters.

Class II (100–125 mm):

In contrast to Class I, these soils are characterized by a larger rooting depth, which varies from 60 – 100 cm. Soil texture is light but with a high degree of stoniness. These soils are also formed on coarse unconsolidated parent materials or solid rock. This AWC-class clearly occupies a greater area than Class I. Both classes appear in association, which indicates that class II represents the less eroded soils. Soils belonging to AWC-Class II are found in nearly all collective vineyards where they cover about 10 % of the area. The exceptions to this pattern are the two collective vineyards Gottesthal, where this class is not found at all and Steil where over 40 % of the surface is covered by Class II.

Class III (126–150 mm):

This class includes soils of intermediate thickness (60 – 100 cm) but with a higher proportion of fine particles (mostly loess clay) and decreasing stoniness. This class also includes locations covered by thick talus (>150 cm) as well as drifting sands. Accordingly, this class is especially widespread along the slopes of the Middle Rhine Valley. Nearly 50 % of the surface area of the collective vineyards Burgweg and Steil are designated as Class III. A second concentration of this class is located on the drifting sand of the Bergstrasse.

Class IV (151–175 mm):

The soils in this class are finer in texture with very little stoniness. The class unites soils formed on Tertiary Marl and luvisols on loess that are less than 150 cm thick. These soils benefit from a higher proportion of fine particles and a deeper rooting depth. These locations benefit from the water storage capacity of the Marl subsoil.

The distribution of these soils corresponds with the underlying geology. Consequently, they are widely found in the Rheingau, to a lesser extent in the Maingau and near absent towards the Middle Rhine Valley. In the Bergstrasse this class is restricted to the drifting sands with a distinct loess content as well as the drifting sand colluvisols, where they occupy less than 10 % of the area. The largest distribution of this class is found in the collective vineyards Gottesthal and Steinmächer.

Class V (176–200 mm):

This class mostly consists of soils with a high loess or loess clay content over Marls. In accordance with the regional geology, the distribution of these soils is limited to the Maingau (Daubhaus) and especially the west–facing slopes of the Rheingau (Erntebringer, Mehrhölzchen, Deutelsberg, Honigberg and Steinmächer). This class also includes waterlogged soils developed on saprolite. Although these clay subsoils are extremely dense and poorly aerated, the vines can profit from the capillary water reserve during long dry periods.

Class VI (> 200 mm):

The locations with the largest water storage capacity are found on thick loess deposits or accumulated colluvial loess substrates (>150 cm) partly mixed with marl debris. They are widely distributed throughout the regions apart from the Middle Rhine Valley. This is the prevailing class in the Rheingau collective vineyards from the eastern parts of Burgweg on to Erntebringer and Steinmächer. They are also the most important soils of the Schlossberg collective vineyard in the Bergstrasse and throughout the Gross-Umstadt region. Class VI soils are slightly less frequent in the Maingau.

Class VII (Gley- and Fluvisols):

This class includes all waterlogged locations and is congruent with the ecological soil group VI. These locations play only a minor role for growing wine since they are rarely stocked.

Summary

The map of the available water contents (AWC) represents the summary of the water storage capacity survey results of the 519 mapping units included in the vineyard soil survey. The distribution of AWC-Classes 2 – 6 differs from that of the ecological soil groups according to ZAKOSEK (1967a) and FRIEDRICH & SABEL (2004) because the present survey only takes into account the plant available water. However, the distribution of the extreme locations belonging to AWC-Class I and VI are congruent with the ecological groups.

The AWC maps contain the basic information relevant for a wide range of problems in the wine-growing regions such as expected yields, nitrate leaching potential as well as unsaturated flow and groundwater studies.

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