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Direct Solar Radiation

1. Introduction

Even today, it is very difficult to produce a detailed, area-wide presentation of the basic climatic factors that influence grape quality. Any endeavor to survey one of the most important of these, the relationship between daily and annual temperature variation and site topography involves a vast effort in terms of scientific instrumentation and data processing. The first climatic site evaluation surveys were therefore restricted to determining the physiologically important heat balance along the northern margin of wine growth using easily obtainable measurements. The first Viticultural Survey of Hesse (ZAKOSEK et al. 1967) already included a map of the maximum potential radiation over the complete vegetation period between April and October in relation to aspect and slope. The justification for this procedure is based on the fact that site temperature is related to the amount of radiation reaching the soil. Part of the incipient solar radiation absorbed by the soil or vegetation cover is emitted back to the surrounding air or the adjacent plants. Therefore, those sites that are optimally inclined to receive solar radiation, will heat up more rapidly than less optimally inclined locations.

However, direct solar radiation is not only determined by astronomical factors. Hourly sunshine duration, atmospheric turbidity and terrestrial shielding also affect the amount of energy available from solar radiation. The so-called Offenbach Evaluation Scheme (BRANDTNER 1973) for calculating radiation takes these effects into account. Long-term measurements of atmospheric turbidity and sunshine duration (1951 – 1980) in various regions of Germany have improved solar radiation calculations.

2. The model for calculating direct solar radiation

2.1 Theory

A good indicator of the thermal conditions of a location is the net solar radiation Q (equation 1). Q is the sum of all short and long wave radiation effects at ground level. Positive values indicate radiation energy surplus, whereas negative values signify energy loss. However, Q can only be estimated for a few locations since net radiation also takes into account soil conditions and plant cover. This is why direct solar radiation (I) is used to indicate thermal conditions. Direct solar radiation correlates to the slope and aspect of the site and is not affected by ground conditions.

Pre-requisite to this procedure is a near balance at our latitude between energy uptake by diffuse sky radiation (D) and atmospheric long wave radiation (G) on one side and loss by terrestrial long wave radiation (Rk) and albedo (A) on the other over long periods of time. Consequently, direct solar radiation (I) is the only site-specific variable in the radiation energy balance equation.

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$$Q = I + D + G - R_k - A \quad (1)$$

This procedure is justified for long-term observations over the complete vegetation period (Hoppmann 1978). Thus, the available energy for a specific location is estimated by measuring the hourly direct solar radiation (Joule/cm^2) for each day during the vegetation period (April 1 to October 31) in correlation with the mean percent hourly sunshine. This procedure explicitly emphasizes the diurnal and annual variability due to site position. In addition to this, it also takes into account the distinct differences in daytime cloud distribution between each location. Cloudiness and sunshine hours are directly correlated.

Direct solar radiation (I) is calculated with the following formula:

$$I = I_o \times \exp(-a_m T_m) \times \sin\beta \quad (2)$$

Here (I) is defined as the maximum possible solar radiation that may pass through a cloudless atmosphere and (I_o) is the intensity of solar radiation at the top of the atmosphere (solar constant). (a_m) is the transmission coefficient of the atmosphere (depending on the thickness of the atmosphere m) (T_m) is the turbidity factor of the atmosphere and (β) is the angle between the incoming rays and the reference plane. Angle (β) is correlated to latitude (ϕ), solar declination (δ), hour angle (T), slope aspect (α) and the angle of

$$\sin\beta = (\sin\phi \times \cos\upsilon - \cos\phi \times \sin\upsilon \times \cos\alpha) \times \sin\delta + (\cos\phi \times \cos\upsilon + \sin\phi \times \sin\upsilon \times \cos\alpha) \times \cos\delta \times \cos T + \sin\upsilon \times \sin\alpha \times \cos\delta \times \sin T \quad (3)$$

inclination (υ) as follows:

$$STRA = I \times (SS / SS_{max}) \quad (4)$$

The actual solar radiation (STRA) reaching the earth surface is reduced by clouds and is given by:

Where SS is the actual duration of sunshine and SS_{ma} is the maximum possible duration of sunshine.

2.2 The effect of turbidity, slope and aspect on direct solar radiation estimates

The atmospheric turbidity factor (Tm) is set at a constant 3.0 for the whole vegetation period in the original model for calculating solar radiation (Brandtner 1973). This calculation is still used for climate evaluations of vineyard locations according to the Wine Economy Law. However, long-term turbidity factor measurements by the Meteorological Observatory Hamburg provided the mean monthly results shown in Table 1.

The turbidity factor is a measure of the extinction of direct solar radiation as it passes through the atmosphere and interacts with aerosols and trace gases including water vapor (Kasten 1984: 28 f.). Revised calculations using the new turbidity factors are compared with the previous ones in the next section.

The calculations were performed for five inclinations 5, 10, 15, 20 and 25 degrees for each

Tab. 1. Mean monthly turbidity factors T_m (Met. Observatorium Hamburg)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
T_m	3.7	4.1	4.6	5.0	5.1	6.0	6.2	5.8	5.5	4.2	3.7	3.6

of the eight directions N, NE, E, SE, S, SW, W and NW at the Geisenheim station located at 50° latitude using the higher and the lower turbidity factors (Table 2).

The mean percent hourly sunshine data used in these calculations was obtained from the 1951 – 1980 measurements (Table 3). The aim of this comparison is to ascertain the effect of the different turbidity factors on the results. This is particularly important when considering the radiation model according to BRANDTNER (1973) used for vineyard evaluations. This model is based on a constant turbidity factor of 3.0.

The results (Table 2) clearly show how the revised turbidity factors affect the calculations. The average available energy from direct solar radiation at high turbidity values (new values) is 45.5 kJoule/(cm^2 ×Vp) less than at low turbidity

Tab. 2. Comparison of the energy gain from direct solar radiation (kJoule/cm^2/Vp) using old and new turbidity factors T_m

Vp : Vegetation period (April 01 – Oct 31) Geisenheim (1951–1980)

kJoule/(cm^2×Vp) slope aspect T_m (old)								
Slope	N 0°	NE 45°	E 90°	SE 135°	S 180°	SW 225°	W 270°	NW 315°
0°	207	207	207	207	207	207	207	207
5°	196	199	206	214	216	214	207	200
10°	183	189	204	218	224	219	204	190
15°	169	178	200	221	230	223	202	179
20°	154	166	195	223	234	225	197	167
25°	138	152	189	224	238	226	192	154

kJoule/(cm^2×Vp) slope aspect T_m (new)								
Slope	N 0°	NE 45°	E 90°	SE 135°	S 180°	SW 225°	W 270°	NW 315°
0°	160	160	160	160	160	160	160	160
5°	151	154	160	166	168	166	160	155
10°	141	146	158	169	174	170	158	146
15°	130	137	155	172	179	173	156	138
20°	118	128	151	174	182	175	152	128
25°	105	116	146	175	185	176	148	116

values (old values). The energy differences vary between 36 and 52 kJoule/(cm^2 ×Vp) depending on exposition. For example, the difference is greater between north and south exposed steep slopes. Since the revised turbidity values form the basis for these maps, these differences must be taken into account when comparing the results with the energy values proscribed by the Wine Business Law.

Table 2 also provides an overview of radiation balance differences in correlation to slope and aspect. The effects of elevation are not considered in this case. The distribution of direct solar radiation emphasizes the profound effect of aspect and slope on the total available energy during the vegetation period from April to October. A north exposed slope inclined at 10 degrees receives about 33 kJoule/(cm^2× Vp) less energy than a comparable south exposed slope. On steeper slopes inclined at 25 degrees, the energy difference increases to about 80 kJoule/(cm^2 × Vp). In these examples the deficits of the north exposed slopes are due to the unfavorable angle of incidence of solar radiation.

Tab. 3: Mean percent hourly sunshine in per mille [‰]

Geisenheim (1951–1980)

MLT	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14	14–15	15–16	16–17	17–18	18–19	19–20	20–21
Apr	0	0	17	223	412	488	541	543	553	559	548	525	500	461	351	95	0	0
May	0	2	158	420	495	535	566	584	580	565	580	562	538	498	458	333	45	0
Jun	0	5	254	464	538	552	555	558	554	538	550	540	510	496	465	389	119	0
Jul	0	4	186	425	511	548	570	576	567	553	565	569	520	501	469	385	73	0
Aug	0	0	34	276	470	536	581	602	612	602	589	558	535	490	422	199	3	0
Sep	0	0	0	57	278	447	523	564	585	576	575	541	499	448	235	13	0	0
Oct	0	0	0	1	54	177	273	341	397	421	431	435	384	235	20	0	0	0

Wiesbaden (1951–1980)

MLT	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14	14–15	15–16	16–17	17–18	18–19	19–20	20–21
Apr	0	0	26	215	403	474	507	519	517	510	507	481	456	407	282	53	0	0
May	0	10	207	430	487	523	551	561	556	536	529	511	499	478	429	248	25	0
Jun	0	43	307	475	516	540	543	534	520	497	513	504	481	456	431	325	80	0
Jul	0	24	248	433	492	531	547	541	534	522	536	538	496	477	450	306	46	0
Aug	0	1	69	318	466	529	563	566	567	558	546	530	509	463	395	141	4	0
Sep	0	0	2	75	314	468	520	532	542	542	532	509	476	399	167	6	0	0
Oct	0	0	0	2	75	228	306	351	377	416	416	408	337	168	6	0	0	0

Darmstadt (1951–1980)

MLT	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14	14–15	15–16	16–17	17–18	18–19	19–20	20–21
Apr	0	2	89	322	456	501	532	540	535	549	547	540	496	450	362	137	3	0
May	0	47	320	465	523	555	580	584	596	576	565	561	546	509	468	357	90	0
Jun	1	111	386	500	547	563	590	574	571	567	563	546	520	487	460	398	185	3
Jul	0	82	355	473	511	543	577	587	578	583	577	566	552	520	475	396	133	1
Aug	0	7	172	413	498	557	591	609	614	611	602	584	541	508	430	228	18	0
Sep	0	0	12	216	432	524	569	601	605	588	588	572	521	454	277	27	0	0
Oct	0	0	0	28	215	331	377	412	436	454	459	454	408	294	52	0	0	0

MLT = Mean local time

2.4 Hourly percent hourly sunshine

Hourly measurements of percent hourly sunshine data, logged by the Campbell Stokes sunshine recorder, is available for some meteorological stations. The mean percent hourly sunshine was calculated from the data recorded between 1951 and 1980 at the stations in Geisenheim, Wiesbaden and Darmstadt (Table 3).

In the absence of meteorological data from the wine-growing region Bergstrasse, the present calculations were based on the dataset from the station in Darmstadt. This more closely characterizes the climate of the Bergstrasse than data from other proximal stations in Mannheim, Oppenheim, Heidelberg or Beerfelden. The mean percent hourly sunshine varies only slightly between stations.

2.5 Reduction of the available energy by terrestrial shielding

The calculations of available energy are only valid for locations where the astronomical equals the true horizon. However, the horizon is often restricted by obstructions, especially in narrow valleys. Consequently, direct solar radiation is shielded during particular periods of time during the day, particularly in the morning and evening. Low vertical obstructions are less important since these only obstruct solar radiation when the sun is low on the horizon and the available energy is low. Very shielded locations such as those found in valleys, near high buildings or vegetation receive less energy when the sun is highest in the sky and the available energy is greatest. The percent energy deficit per hour can be calculated by multiplying the effective direct solar radiation at the specific hour with the value from the hour angle / azimuth nomogramme in which the local horizon has been outlined. The present radiation maps do not take these deficits due to terrestrial shielding into account.

2.6 Correcting the available energy from direct solar radiation for the effects of elevation

Calculations of the actual available energy from direct solar radiation at a specific location do not take the effects of elevation into account. The sites available for wine-growing do not usually extend beyond 200 m in the vertical. This small difference in elevation has little effect on the energy balance. However, the reduction of temperature with increasing elevation, independent of solar radiation, plays a significant role in the heat balance within a vineyard. The outcome of these differences is determined by air density differences and the reduction of atmospheric pressure with increasing elevation. Thus, the absolute upper wine-growing limit in the Rheingau lies at about 280 m above sea level. This limit is solely determined by growing detrimental thermal effects with increasing elevation. The upper wine-growing limits increase with decreasing geographic latitude.

The temperature regime is determined by ascertaining the energy balance in relation to the elevation of the local valley bottom above a latitude-dependant reference height as well as the elevation of the site above the local valley bottom.

The temperature regime is expressed as energy values. The gradients per 10 m increment are converted to energy values using the specific heat capacity of air ($C_p \approx 1.0$ Joule/g/degree). These are presented as f-correction factors in Fig. 1.

The degree by which temperature decreases with elevation also depends on slope aspect. The H-correction factor depicted in Fig. 2 takes aspect into account.

Studies of temperature gradients along slopes (BAUMGARTNER 1960, 1961; HOPPMANN 1988) show that temperature decrease significantly correlates with elevation and slope aspect. For this reason, the elevation of the sites in relation to the local valley floor must be classified according to slope aspect. The resulting thermal conditions are presented in Fig. 2.

The overall available energy reduction therefore depends on the elevation of the local valley bottom above the particular reference height and the elevation of the site above the local valley floor. This decrease is accounted for in the Φ and H correction factors introduced to the calculations. This remaining energy is then available to the vines and determines grape quality. Therefore, the maps of the decreased available energy provide first indications of the quality of a wine location.

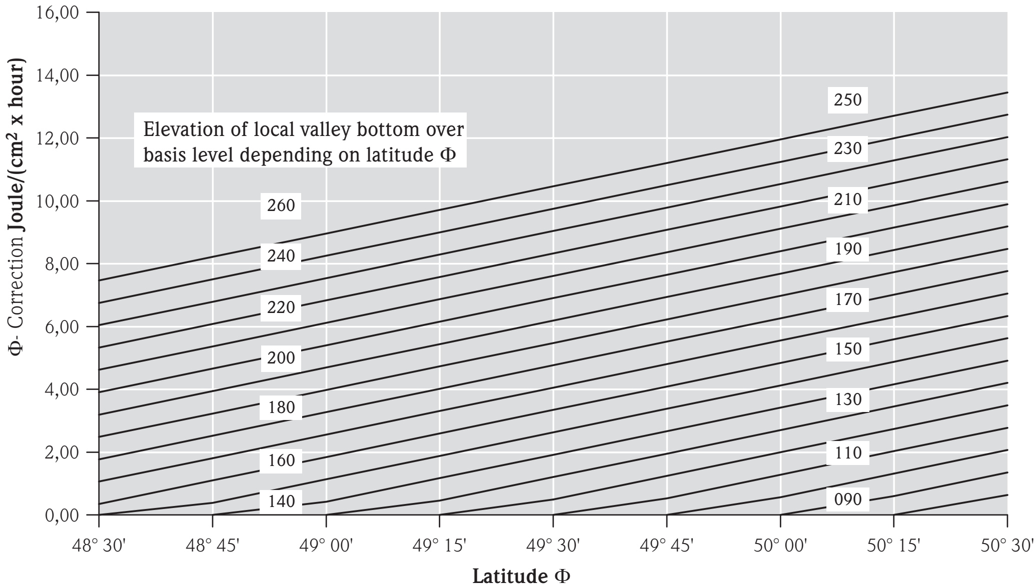

Fig. 1. Φ- Correction factors for the elevation of local valley bottom above a basis level, depending on latitude Φ in Joule/(cm^2 x hour)

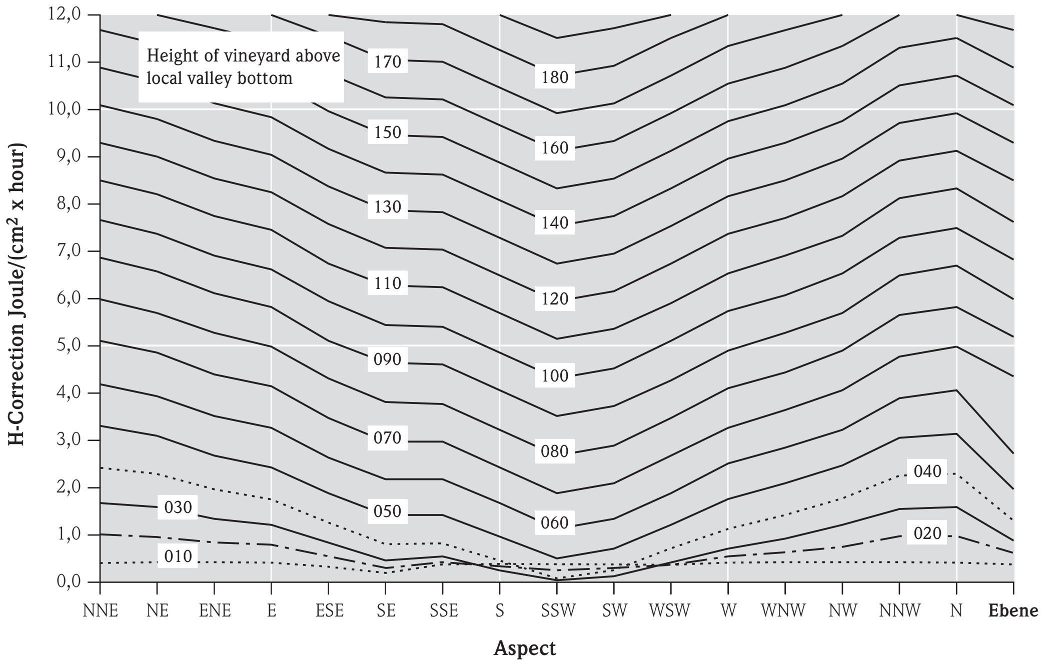

Fig. 2. H-Correction factors for a single vineyard depending on the elevation above the local valley bottom in Joule/(cm² x hour)

3. Radiation maps I and II for the wine growing regions in Hesse

3.1 Map color scheme and explanations

The available energy from direct solar radiation was calculated using the digital elevation model (DEM) with a grid spacing of 20 m. The slope and aspect of the locations required for the calculation were obtained by a geographic information system (GIS). Smoothing effects cannot be avoided in this procedure. Terraces and other steps in the terrain were not taken into account. The results were computed with and without Φ **and H** correction factors and plotted on Map I (not corrected for elevation) and Map II (corrected for elevation).

The results for both calculations differentiated into seven available energy classes (kJoule/(cm² × Vp)), each represented by a color as follows (Table 4):

The correlations will be explained using Map

Tab. 4. Distribution of available energy in the actual wine-growing areas

Classes	1	2	3	4	5	6	7
Class limits	<106	106–120	121–135	136–150	151–165	166–180	>180

II (reduced available energy). The relationship between elevation and available energy can be distinguished on the SE to SW facing slopes of the Rheingau. The available energy at the higher locations over 220 m above sea level is less than 135 kJoule/($cm^2 \times Vp$) and therefore far below average values, unless compensated by a very beneficial slope. The advantageous effect of slope is illustrated in Map I where high energy gains (red zones) are also found in some higher locations. This is particularly evident in the locations near Rüdesheim, Hallgarten, Kiedrich and Rauenthal. However, in the reduced available energy map the yellow and green colors of the same locations indicate that these have been placed into lower categories with reduced energy values.

In contrast, the average energy gain for almost level to level sites near the valley floor is 135 to 165 kJoule/($cm^2 \times Vp$). The differences between the two maps for these sites are very small. The maps indicate that the slopes immediately above these locations are the best sites in terms of energy gain. These sites benefit from advantageous slope and aspect.

3.2 Energy gain from direct solar radiation in kJoule/($cm^2 \times Vp$) for the wine growing regions in Hesse in relation to mean sunshine hours, slope and aspect, independent of elevation

The highest energy gain from direct solar radiation was calculated for the Schlossberg in Heppenheim. This south facing slope is inclined at 26° and receives 190 kJoule/ ($cm^2 \times Vp$). The lowest energy gains were calculated for a north facing, 34° slope in the Bodenthal between Lorch and Assmannshausen and a NNW-facing, 36° slope east of Zell in the Bergstrasse region. Both sites receive 77.5 kJoule/($cm^2 \times Vp$) from direct solar radiation. These two locations only serve to define the study area – no wine is produced here.

Map I clearly shows the correlation between energy gain, slope and aspect. Almost the entire Rheingau between Rüdesheim and Wiesbaden with its gradual south-facing slopes receives 151–165 kJoule/($cm^2 \times Vp$) from direct solar radiation. Individual collective vineyards, usually with slopes greater than 10°, can receive more than 165 kJoule/($cm^2 \times Vp$) in this area. This is the case for the collective vineyards Burgweg (Rüdesheim), Erntebringer (Johannisberg), Steinmächer (Rauenthal), Deutelsberg (Hattenheim), and Wildsau (Martinsthal), but also for the locations situated along the transition zone to the Rheingau Mountain Range.

All locations between Rüdesheim and Lorch are very steep. Aspect is a major quality-determining factor of these sites. Almost all S to SSW facing slopes achieve values greater than 165 kJoule/($cm^2 \times Vp$). In contrast most of the W to NW facing slopes receive less than 150 kJoule/($cm^2 \times Vp$). The S-facing gradual slopes at the locations Hochheim, Mainz-Kostheim, Wicker and Flörsheim receive about 150 kJoule/($cm^2 \times Vp$) from direct solar radiation.

The Bergstrasse region is characterized by steep E-W orientated valleys and therefore extreme small-scale energy gain variability. The S-facing slopes on the northern side of the valleys often receive more than 165 or 180 kJoule/($cm^2 \times Vp$) from direct solar radiation. However the opposite slopes usually receive less than 135 kJoule/($cm^2 \times Vp$).

3.3 Energy gain from direct solar radiation in kJoule/(cm²× Vp) for the wine growing regions in Hesse in relation to mean sunshine hours, elevation, aspect and slope

The elevation corrections integrated in Map II have a profound effect on the results presented in Map I. The energy gains from direct solar radiation are almost always lower than that calculated without compensating for elevation. As before, the highest energy gain was calculated for the Heppenheimer Schlossberg. The 26° slope receives 187 kJoule/(cm² ×Vp).

Map II clearly shows how energy gain from direct solar radiation depends not only on slope and aspect but also on elevation. This is exemplified in Map II in the central part of the Rheingau between Rüdesheim and Wiesbaden. Here the site classifications are clearly more differentiated than in Map I. Energy gains of more than 165 kJoule/(cm² × Vp) are still achieved in the steeper collective vineyards Burgweg (Rüdesheim), Erntebringer (Johannisberg), Steinmächer (Rauenthal), Deutelsberg (Hattenheim) and the vineyard Wildsau (Martinsthal). However, the higher sites are no longer represented in these classes. Many of the moderately steep slopes of the central Rheingau are found in the 151 to 165 kJoule/(cm² × Vp) class. These values are also achieved by the SW-facing slopes of the relatively shallow valleys in this region. The NE-facing slopes of these valleys as well as the slightly higher regions of the Rheingau between Rüdesheim and Wiesbaden are placed in the 136 to 150 kJoule/(cm² ×Vp) class. The energy gained by the areas located at the transition to the Rheingau Maountain Range decreases to values below 135 kJoule/(cm²× Vp). Most of these locations are no longer in production.

Map II also shows that the only locations between Assmannshausen and Lorch to gain more than 165 kJoule/(cm²× Vp) are mostly limited to those closest to the Rhine near Lorch. Surprisingly, this value is only achieved in a few very small areas within the famous red wine location in Assmannshausen. The map shows a clear decrease of energy gain from direct solar radiation with increasing elevation.

The corrections for elevation have little effect on the energy gain from direct solar radiation in locations in the communities Hochheim, Mainz-Kostheim, Wicker and Flörsheim. Map II also shows an energy gain around 150 kJoule/(cm² × Vp) for these sites. None of these lie higher than 70 m above the valley floor.

A view of the Bergstrasse region in Map II shows a marked difference between N and S-facing slopes as well as between the lower sites along the Upper Rhine Rift Valley and the higher transition zones towards the Odenwald Mountain Range. The highest energy gains of 160 and 180 kJoule/(cm² × Vp) are achieved in respective low lying locations along the steep S-facing sides of the large valleys near Bensheim and Heppenheim. The lowest values are not achieved in the locations on the opposite side of these valleys, but on the highest N-facing slopes. Many of these sites gain less than 120 kJoule/(cm² × Vp).

3.4 The distribution of elevation dependant available energy in individual wine growing areas

The study area covered by Map I and II is slightly larger than the actual wine growing region, to facilitate the interpolation between individual points in the area. The detailed results of the distribution of reduced available energy in the actual wine growing areas in production and especially of individual locations are presented in the following tables (Table 5.1 and 5.2).

4. References

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Tab. 5.1 Distribution of height reduced available energy in the actual vinegrowing areas [kJoule/(cm²xVp)]

Rheingau

			1	2	3	4	5	6
Lorchhausen	1 Rosenberg			x	x	x	x	x
	2 Seligmacher			x	x			
Lorch	3 Schloßberg			x	x			
	4 Kapellenberg			x	x			
	5 Krone			x	x			
	6 Pfaffenwies			x	x			
	7 Bodental-Steinberg			x	x			
Assmannshausen-Aulhausen	8 Frankenthal	Collective Vineyard Steil			x	x		
	9 Höllenberg			x	x			
	10 Hinterkirch				x	x		
	11 Berg Kaisersteinfels				x	x		
Rüdesheim	12 Burg Roseneck	Collective Vineyard Burgweg			x			
	13 Berg Rottland		x	x	x			
	14 Berg Schloßberg		x	x	x			
	15 Bischofsberg			x	x			
	16 Drachenstein				x			
	17 Kirchenpfad					x		
	18 Klosterberg					x	x	
	19 Klosterlay				x	x		
	20 Magdalenenkreuz			x	x			
	21 Rosengarten			x				
Geisenheim	22Rothenberg			x	x			
	23 Kläuserweg				x			
	24 Fuchsberg			x	x			
	25 Kilzberg				x	x		
	26 Mäuerchen				x	x		
	27 Mönchspfad				x	x		
	28 Schloßgarten				x			
	29 Klaus			x	x			
Johannisberg	30 Schwarzenstein	Collective Vineyard Erntebringer				x	x	
	31 Vogelsang				x	x		
	32 Hölle			x	x			
	33 Hansenberg				x	x		
	34 Goldatzel				x	x	x	
	35 Mittelhölle				x	x		
	A Schloß Johannisberg			x	x			
Winkel	36 Gutenberg	Collective Vineyard Honigberg			x			
	37 Dachsberg				x	x	x	
	38 Schloßberg				x	x		
	39 Jesuitengarten				x			
	40 Hasensprung				x	x		
	41 Bienengarten				x			
	B Schloß Vollrads				x	x		
Mittelheim	42 St. Nikolaus				x			
	43 Edelmann				x	x		
	44 Goldberg				x	x	x	
Oestrich	45 Klosterberg	Collective Vineyard Gottesthal			x	x	x	
	46 Lenchen				x	x		
	47 Doosberg			x	x			
	C Schloß Reichartshausen				x			

Rheingau

			1	2	3	4	5	6
Hattenheim	48 Mannberg	Collective Vineyard Deutelsberg		x	x			
	49 Nußbrunnen			x	x			
	50 Wisselbrunnen				x			
	51 Hassel				x	x		
	52 Heiligenberg				x	x	x	
	53 Schützenhaus				x	x		
	54 Engelmannsberg			x	x			
	55 Pfaffenberg				x			
	D Steinberg				x	x		
Hallgarten	56 Schönhell	Collective Vineyard Mehrhölzchen			x			
	57 Würzgarten					x	x	
	58 Jungfer				x	x	x	
	59 Hendelberg				x	x	x	
Erbach	60 Marcobrunn			x	x			
	61 Schloßberg				x			
	62 Siegelsberg				x			
	63 Honigberg				x	x	x	x
	64 Michelmark			x	x	x		
	65 Hohenrain			x	x			
	66 Steinmorgen			x	x			
	66a Rheinhell				x			
Kiedrich	67 Klosterberg	Collective Vineyard Heiligenstock			x	x	x	x
	68 Gräfenberg				x	x		
	69 Wasseros				x	x	x	
	70 Sandgrub				x	x		
Eltville	71 Taubenberg			x	x	x		
	72 Langenstiick				x	x		
	73 Sonnenberg				x	x		
	74 Rheinberg				x			
	75 Sandgrub				x	x	x	x
Rauenthal	76 Balken	Collective Vineyard Steinmächer		x	x	x	x	x
	77 Gehrn					x	x	x
	78 Wölfen				x	x	x	
	79 Rothenberg			x	x	x		
	80 Langenstück					x	x	
	81 Nonnenberg				x	x	x	
Martinsthal	82 Wildsau			x	x			
	83 Langenberg			x	x	x		
	84 Rödchen				x	x		
Niederwalluf	85 Berg-Bildstock				x	x		
	86 Walkenberg			x	x			
	87 Oberberg				x	x		
Oberwalluf	88 Fitusberg				x	x		
	89 Langenstück				x	x		
Wiesbaden-Schierstein	91 Dachsberg				x	x		
	92 Hölle				x	x		
Wiesbaden-Frauenstein	93 Marschall				x	x	x	
	94 Homberg				x	x		
	95 Herrnberg				x	x		
Wiesbaden-Dotzheim	96 Judenkirsch				x	x		

Vp = Vegetationsperiode (01.04.–31.10.)

Class		
1	> 181	kJoule/(cm²×Vp)
2	166–<=180	kJoule/(cm²×Vp)
3	151–<=165	kJoule/(cm²×Vp)
4	136–<=150	kJoule/(cm²×Vp)
5	121–<=135	kJoule/(cm²×Vp)
6	106–<=120	kJoule/(cm²×Vp)

Tab. 5.2 Distribution of height reduced available energy in the actual vinegrowing areas [kJoule/(cm^2xVp)]

Hochheim

Collective Vineyard Daubhaus	1	2	3	4	5	6
Mainz-Kostheim						
97 Reichesthal			x			
98 Weiß Erd			x	x		
99 Steig			x	x		
100 Berg				x		
Hochheim						
101 Königin Victoriaberg			x			
102 Hofmeister			x	x		
103 Stielweg			x			
104 Sommerheil			x			
105 Hölle			x			
106 Domdechaney			x			
107 Kirchenstück			x			
97 Reichesthal			x			
100 Berg			x	x		
108 Stein			x			
109 Herrnberg			x	x		
Wicker						
110 Stein			x	x		
111 Goldene Luft			x			
112 König-Wilhelms-Berg				x		
113 Nonnenberg				x		
Flörsheim						
109 Herrnberg			x	x		

BERGSTRASSE

	Collective Vineyard	1	2	3	4	5	6
Heppenheim – Erbach – Hambach	Schloßberg						
1 Eckweg		x	x	x	x	x	
2 Guldenzoll			x	x			
3 Maiberg		x	x	x	x		
4 Steinkopf		x	x	x	x		
5 Centgericht			x	x			
6 Stemmler			x	x			
Bensheim	Wolfsmagen						
7 Paulus			x	x			
8 Hemsberg			x	x	x	x	
9 Steichling		x	x	x			
10 Kirchberg			x	x	x		
11 Kalkgasse		x	x	x	x		
Bensheim-Schönberg	Rott						
12 Herrnwingert			x	x	x		
Bensheim-Auerbach	Rott						
13 Fürstenlager		x	x	x	x		
14 Höllberg			x	x	x		
Zwingenberg	Rott						
15 Alte Burg			x	x	x		
16 Steingeröll		x	x	x	x	x	

Vp = Vegetation period (01.04.–31.10.)

Class

Class		
1	> 181	kJoule/(cm^2×Vp)
2	166–<=180	kJoule/(cm^2×Vp)
3	151–<=165	kJoule/(cm^2×Vp)
4	136–<=150	kJoule/(cm^2×Vp)
5	121–<=135	kJoule/(cm^2×Vp)
6	106–<=120	kJoule/(cm^2×Vp)