SOLAR ENERGY MAPPING

by

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Napenergia térképezés. A dolgozat a direkt sugárzás tenyész időszakban érkező hőenergiája eloszlásának számításával foglalkozik. Az érkező hőenergia eloszlása adott földrajzi szélességű hegyi terepen a lejtő szögétől és dőlésirányától függ. Ennek az eloszlásnak térképes ábrázolása elősegítheti a művelési rendszerek tervezését Magyarország hegyvidéki mezőgazdasági területein.

This paper is a brief information on computing heat from direct solar radiation during the growing season. The distribution of incidenting heat depends on the inclination and exposure of slopes in a hill region of a given latitude. A map showing this distribution can contribute to the re-designing of cropland pattern of hill agricultural areas in Hungary.

Agrogeographical research is one of the recently developed branches of landscape study in Hungary. It surveys and assesses the effects of physical geographical factors on crop cultivation. Its aim is to produce some kind of a cropland pattern map showing the order of preference of different plants on the basis of physical environmental endowments. These cropland pattern maps could be then directly applied by state farms and agricultural cooperatives.

Unlike the quantity of solar radiation in the growing season, unfavourable soil, precipitation and even topographic endowments can be at least theoretically - improved over large areas (consider amelioration, irrigation, reclamation and strip cultivation, etc). Consequently, wedecided to construct a method for mapping solar radiation heat to enable agricultural farms on hilly terrains to adjust their field boundaries to the amount of heat received complying with the requirements of plants.

The basic idea we used is extremely simple. We superposed the slope exposure (*Fig. 1*) and slope angle (*Fig. 2*) maps of the same area. The resulting mosaic map shows an areal distribution of heat (*Fig. 3*). The slope exposure has *8* categories (*N,W,S,E,NW,SW,SE,NE*). The slope category map - as usual in Hungarian agricultural application - has the following classes: *5-12°, 12-17°, 17-25°, 25°< and the flat surface 5°>*. Thus, besides constructing slope exposure and angle maps we need a table showing radiation heat for each of the $8 \times 4 + 1$ topographic conditions. Using the so called "cloud filter" factor we can compare the heat requirement of a plant during the growing season and the mosaic map showing the areal distribution of heat.

The mountain we chose as an example is found in *West Transdanubia. Mount Somló* is *432* metres high, built up of basaltic rocks and famous for its vineyards and grape vine plantations. The algorithm for computing the heat distribution table is described below.

Solar constant: $I_o = 1354\ W.m^{-2}$ at a mean Sun-Earth distance

$$I = \frac{\text{actual Sun-Earth distance}}{\text{mean Sun-Earth distance}} \quad \text{given for each day}$$

q = complex transmissivity coefficient of the atmosphere ($q = 0.93$)
A = opacity factor of the atmosphere (eg. $A = 3.5$)
h = Sun's elevation angle
= latitude
t = Sun's hour-angle
t_o = Sun's hour-angle at sunset ($-t_o$ = sun hour-angle at sunrise)

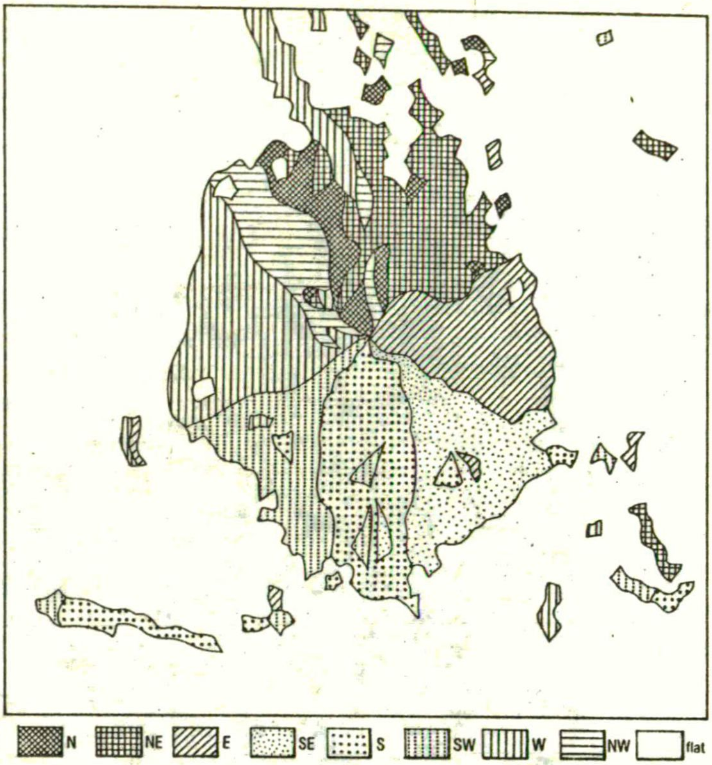


Fig. 1. Slope exposure map of Mt.Somló

Knowing the Sun's elevation angle in hour-angle function is:

$$\sin h = \sin \varphi \cdot \sin \delta + \cos \varphi \cdot \cos \delta \cdot \cos t \qquad /1/$$

Hence the hour-angle of sunset ($h = 0$):

$$\cos t_0 = -tg\, \varphi \cdot tg\, \delta \qquad /2/$$

a = Sun's azimuth

The relationship between azimuth and hour-angle:

$$ctg\, a = \frac{\sin \varphi \cdot \cos t - tg\, \delta \cdot \cos \varphi}{\sin t}$$

$$a = arc\, ctg \frac{\sin \varphi \cdot \cos t - tg\, \delta \cdot \cos \varphi}{\sin t} \qquad /3/$$

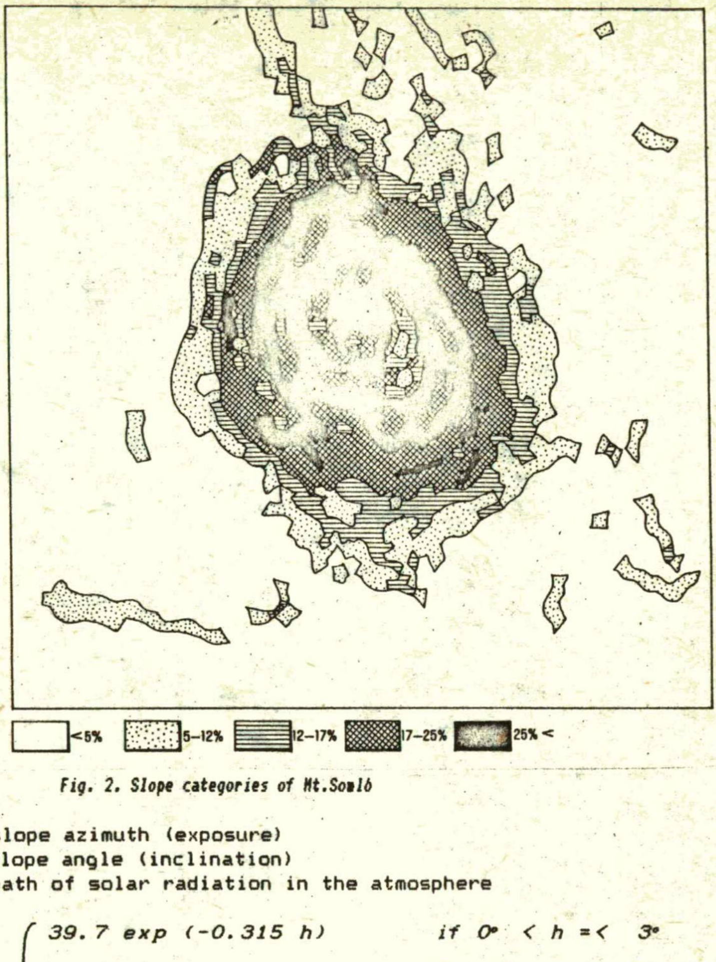


Fig. 2. Slope categories of Mt.Somló

a_i = slope azimuth (exposure)
i = slope angle (inclination)
z = path of solar radiation in the atmosphere

$$z = \begin{cases} 39.7 \exp(-0.315\, h) & \text{if } 0° < h =< 3° \\ 1^{-\sin h} - 66.6\, h^{-2.58} & \text{if } 3° < h =< 8° \\ 1^{-\sin h} - 161.8\, h^{-3.02} & \text{if } 8° < h =< 35° \\ 1^{-\sin h} & \text{if } h > 35° \end{cases}$$

Direct radiation onto a horizontal flat surface (I_f) in a particular case:

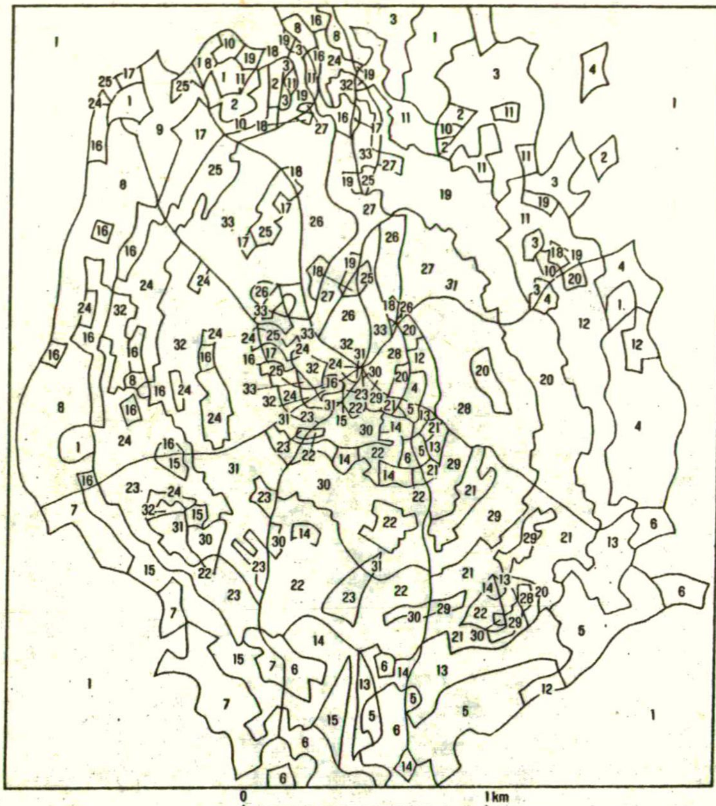
$$I_f = I_o . l^{-2} . q^{Az} . \sin h \qquad /5/$$

Let us transfer the value of the solar constant from s into radian:

$$C = (86400/2\ ).1354\ W.m^{-2} = 18618836\ W.m^{-2} = 18.62\ MW.m^{-2} \qquad /6/$$

Direct radiation received by a sloping surface (I_s) at a given moment:

$$I_s = I_o . l^{-2} . q^{Az} . [\sin h . \cos i + \cos h . \sin i . \cos (a-a_i)] \qquad /7/$$



Slope angle	flat	EXPOSURE							
		N	NE	E	SE	S	SW	W	NW
< 5%	1	–	–	–	–	–	–	–	–
5–12%	–	2	3	4	5	6	7	8	9
12–17%	–	10	11	12	13	14	15	16	17
17–25%	–	18	19	20	21	22	23	24	25
25% <	–	26	27	28	29	30	31	32	33

Fig. 3 Heat distribution map of Mt. Somló

S = sum of daily radiation

Sum of daily radiation can be obtained by the integration of the function describing radiation in a particular case from sunrise to sunset:

$$S = C.I^{-2} \quad q^{A z} \, [\sin h.\cos i + \cos h.\sin i.\cos (a-a_i)].dt \qquad /8/$$

- the variables are expressed by (z, m, a); it can be solved by /1/, /3/, /4/.
- integration limits can be calculated from /2/.
- value of C constant is given in /6/.
- value of is given for each day and may be regarded as a constant for each day.

These formulas of the above algorithm allow the automated computation of direct solar radiation heat received by 33 types of terrain (with varying exposure and angle) for each day of the growning season (183 days on the average in Hungary).

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