Changes in solar radiation energy and its relation to monthly average temperature

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In the analysis of problems of surface evapotranspiration, the conclusion is that the potential and actual values of water surface evaporation and those of transpiration of plants are different in different months of the year, depending on monthly temperature averages. In the spring and early summer evapotranspiration has higher values than in the autumn months.

The analysis of the changes of monthly values of solar radiation energy including global radiation, radiation energy reaching flat surfaces and specific energy that can be utilized by solar cells give the result that the energy values estimated for late summer and autumn on the basis of spring and early summer changes in radiation energy show a deficit. As an annual average, actual values "fall behind" potential values by 9 – 17% and if the deficit is projected to autumn months involved, the extent of the "shortage" is 23 – 30%. Besides this energy deficit, the decreased evapotranspiration also results from the vegetation cycle of plants and from the fact that in summer months there can be a shortage of groundwater, too.

Key words: *solar radiation, evapotranspiration, temperature averages*

It was investigated how the solar radiation energy changes in the course of the year. The energy reaching the Earth surface in the form of direct or scattered radiation determines the temperature of both the surface and the lower atmosphere, which, in turn, determines the evaporation capacity and climatic features. The performance of scattered radiation is on the average 12 – 25% of that of direct radiation. In the investigation of evaporation and in the dimensioning of solar energy based equipment, the total radiation (TOT) is usually taken into account, which is the sum of direct (DIR) and scattered radiation [1, 2].

The radiation of the Sun reaching the Earth has different values during the year. The fluctuation results from the Earth's movement on an elliptic orbit and from the obliquity (in relation to the elliptic orbit) of the rotation axis. The annual changes in the angle of incidence (declination) of sunrays results in the changes of radiation energy. Naturally, the values of radiation energy are affected by the tilting and the direction (horizontal or vertical, and, in the latter case, northern, southern, eastern or western) of the inclination surface.

Changes in the monthly values of global radiation, as connected to the monthly mean temperature values typical of the Mátra-Bükkalja region, were examined on the basis of the mean values published in [1].

Figure 1 shows the changes in the values of monthly global radiation (E_{gh}) as the function of monthly mean temperature. In the first five months of the year, the energy amount increases in an approximately linear way. In June and July there is a degressive tendency, whereas from August the level of energy belonging to the same average temperature is significantly lower than in the spring and early summer months.

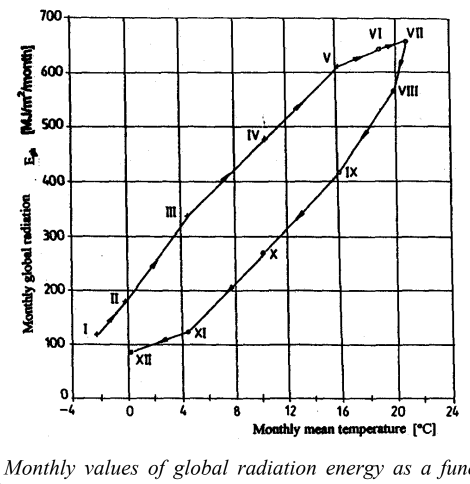

Fig. 1 Monthly values of global radiation energy as a function of monthly mean temperature

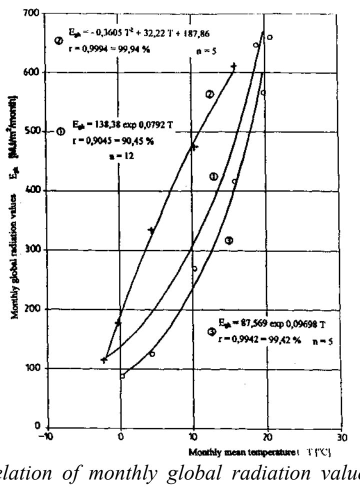

Fig. 2 The relation of monthly global radiation values and mean temperature

Figure 2 shows the regression functions describing the changes in monthly average temperature and radiation energy values. Curve 1 shows the regression function drawn from the data of 12 months. Curve 2 is the

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one belonging to the 5 months from January to May, while curve 3 is made on the basis of the data of the 5 months from August to December.

As can be concluded from the value of the correlation coefficient, the reliability of the annual falls significantly below that calculated on the basis of the "spring" and "autumn" months. It is therefore justified to calculate the values of radiation energy for two different periods of the year on the basis of the two separate functions. The situation that in the spring and early summer months and in the autumn and winter months a different energy belongs to the same temperature may occur due to the influence of geometrical features of the movement of the Earth (in our country the ground surface is covered by clouds and fog to a greater extent in the autumn – early winter than in the spring – early summer period).

Figure 3 was developed for the tendency defined by the global radiation values in the spring-early summer months (curve 2) as a potential radiation value (PE_{gh}) for the whole year (every month).

In this case the actual radiation values for January – May are identical to the potential radiation values for the particular month, while the actual values (TE_{gh}) for June – December fall behind the potential values. From June, there is a "global radiation deficiency" in both the values of the particular months and in the annual sum total, probably arising from the above mentioned geometry of the Earth movement and autumn clouding. On the basis of the calculation figures in Figure 3, the global radiation "deficiency" of the second half of the second half of the year is 16.12% of the annual potential value. If the "deficiency" is only related to the potential radiation value of the months concerned (June – December), the extent of deficiency id 23.30%. The extent of deficiency shows the following values in the particular months: June 4.5%, July 7.0%, August 17.3%, September 32.5%, October 42.1%, November 63.2%, December 50.0%.

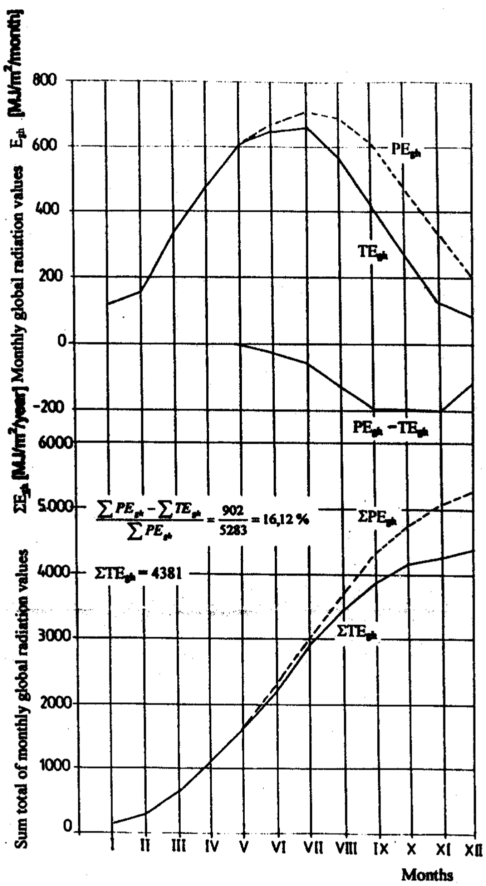

Fig. 3 Monthly and annual values of global radiation at average temperature conditions in Hungary

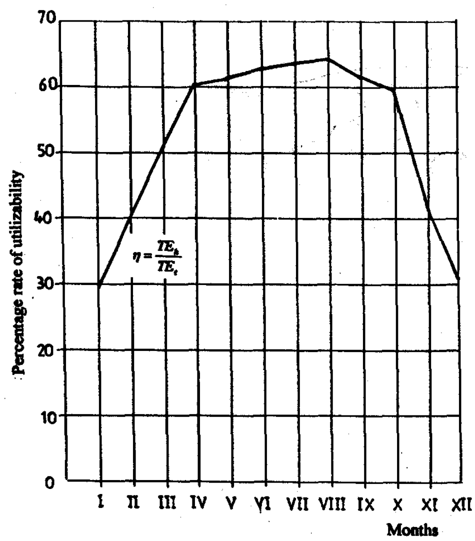

Fig. 4 The rate of the utilizability of solar radiation energy in the different months of the year

The time changes of solar radiation energy were also analysed on the basis of the data in Figure 1.20 of [1]. According to the analysis, the "deficiency" of annual total radiation energy is 17.25% and, if related to the June – December "potential" values, it is 25.50%. In June the deficiency is 1.9%, in July 8.4%, in August 18.2%, in September 36.6%, in October 47.7%, in November 57.1% and in December 60.0%.

So according to the solar radiation energy data in [1], the "shortage" of energy at the end of the summer and in autumn is 16 – 17%, while the "shortage" related to the potential values of the months concerned (July – December) is 23 – 25%.

The annual variation of long term radiation values (TOT) measured on flat surface were also examined on the basis of the data in Table 8.4 of [2]. The calculation gave the "shortage" of annual radiation energy of 13.7%; if we relate it only to the months concerned (July – December), the result is 24.50%. On the whole, these results confirm the previous data.

The annual variation of solar energy was also examined on the basis of the data in the figure in [3]. On the basis of the investigation of monthly total radiation values (E_t), the "annual deficiency" turned out to be 8.9%, whereas on the basis of the June – December data it was 13.7%.

The examination of the values of utilizable solar radiation energy (E_h) gave an "annual deficiency" value of 9.2% and the deficiency value for the months concerned turned out to be 29.6%. The November shortage of 73.1% is conspicuously high, which probably results from the cloudy and foggy weather conditions in this month, as the deficiency of total solar radiation energy is "only" 48.6% in November.

Thus the examination of the different radiation values gave the result comparable to the annual "potential" energy value estimated on the basis of the tendency in the changes in spring – early summer temperature – energy relationship. There was a 9 – 17% annual average deficiency in solar energy while the deficiency related to the autumn months concerned appeared to be 23 – 30%. On the basis of the results we assume that this should be taken into consideration in the analysis of the problems of evapotranspiration.

Figure 4 gives the relationship between utilizable (TE_h) and actual (TE_t) radiation energy. It can be seen that the "utilizability" of radiation energy is above 50% in the months March – October (51% in March) whereas there is a more moderate utilizability in November – February. In the future course of research it will be appropriate to compare the data in Figure 4 with the monthly values, the annual variation and the rates of evapotranspiration.

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