MOISTENING IRRIGATION IN VITICULTURAL REGIONS OF SLOVAKIA

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SUMMARY

The irrigaton requirements by hypothetical grape vine stands for climatological stations distributed in individual viticultural regions of Slovakia were calculated using an AFSIRS model. The values were determined for the period between 1971 and 2000 for sandy and loamy soils. Regression associations, that have been derived between irrigation requirements and precipitation totals in April to September, enable us to complete the calculation of the complemnetary irrigation requirements also for sites where caculations were not carried out (**Figure 3**), but for which precipitation totals are known. Regression associations were derived also for irrigation requirements with the saturation to 80 % of utilisable water capacity (**Figure 4**), what corresponds to an apparently dry year.

Not only this must necessarily be taken into account when the aforementioned values are to be applied in irrigation practice, but also the non-inclusion of losses coefficient of given irrigitation equipment into calculations as well. Despite that the values, which we have calculated, relatively well correspond to those published earlier, our work is important as new methods applicable in our conditions have been verified. At the same time association based on values from ten sites have been determined, that are interpolable and enable to calculate irrigation requirements for sites within any grape-vine region in Slovakia.

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1. INTRODUCTION

In 1970s and 1980s a "biological-curve coefficient" method was applied to caculate water demand as input values for water balance equation in retrospective method applied to establish irrigation requirements by individual crops grown in principal irrigated areas of the former Czecho-Slovakia. Thus determined values have been incorporated into the still applicable Czech standard ČSN 75 0434. Despite that this standard was not implemented into Slovak legal order, a new one has not been adopted yet. In the aforesaid standard the following guide values of (sprinkle) irrigation requirements as regards grape vine have been established for Podunajská Lowland and Východoslovenská Lowlands - 100 mm and 50 mm respectively.

SPITZ (1976) applied retrospective irrigation bilancie method to determine mean irrigtaon množstvá required by grape vine in Záhorská Lowland as 57mm and with the saturation to 80 % of utilisable water capacity as 100 mm. For Východoslovenská region these values have been established as 50 mm and 121 mm.

2. METHOD

In course of the recent five decades the methodological development has brought about the equation by Penman equation as modified by MONTEITH as a certain standard, whereby meteorological data measured at relatively sufficient number of stations are put in. This equation (KOHUT, 2003) is applied to establish referential evapotranspiration values, however, usually considered as for turf - according to a method by FAO - and it is generally considered as the approach for dealing with avaporation issues.
The calculations for daily or any other intervals on the basis of basic meteorological data (air temperature, air humidity expressed as water vapour pressure or relative air humidity, duration of sunlight or global radiation, wind speed), while all other parametres are for the calculation at given intervals set on constant levels. In this way individual, mutually differing regions may relatively good be compared.
The basic formula to calculate referential evapotranspiration of turf according the FAO method is as follows:

$$ET_0 = \frac{0{,}408 * \Delta * (R_n - G) + \gamma * \frac{900}{T + 273{,}16} * u_2 * (e_s - e_a)}{\Delta + \gamma * (1 + 0{,}34 * u_2)}$$

with ET_o referential evapotranspiration [mm.d^{-1}],
R_n radiation on a hypothetical surface, in fact its balance [MJ.m^{-2}.d^{-1}],
G heat flow in a soil [MJ.m^{-2}.d^{-1}],
T air temperature in 2 m [^{o}C],
u_2 wind speed in 2 m height [m.s^{-1}],
e_s saturated water vapour pressure at the temperature measured in a thermometer shelter [kPa],
e_a water vapour pressure calculated from the temperature measured in a thermometer shelter [kPa],
$e_s - e_a$ saturation deficit [kPa],

Δ the slope of water-vapour curve at a given temperature, i.e. derivation of the association between the specific humidity of a water-vapour saturated air and its temperature [kPa.ºC $^{-1}$],

γ psychometric constant [kPa.ºC^{-1}].

The fundamental importance of in such a way determined evapotranspiration is its possible application in dealing with questions concerning actual evapotranspiration. The evapotranspiration of any crop under standard conditions can be determined as the product of referential evapotranspiration and a dimensionless coefficient of the given crop. The values of the latter have been empirically established:

$$ET_c = K_c * ET_0$$

with: ET_c evapotranspiration of a given crop [mm.d^{-1}],
K_c coefficient of a given crop,
ET_o referential (potential) evapotranspiration [mm.d^{-1}].

Different values of K_c have been applied by authors world-wide and their overview is given in **Table 1**. For grape vine ALLEN (1998) indicated the K_c values of 0.30, 0.70 and 0.45 in its following stages: the initial ones, that of the highest water uptake and the late-season ones respectively. In summer, the K_c values of table grape vine use to increase to up to 0.85. The values of 0.85 and 0.35 have been indicated by SNYDER *et al.* (2002) for the stage of the highest water demand and late-season respectively. These values apply to cases with inter-row bare fallow, if this space is turf or otherwise covered, the K_c values should be increased approximately by 0.35 as indicated by SNYDER et al. (2002).

Table 1: Biological-curve coefficients K_c for grape vine as referred to different authors

Reference	**V**	**VI**	**VII**	**VIII**	**IX**	**X**
Stein T.M.	0,50	0,65	0,75	0,80	0,75	0,65
Williams L.E. (cit. podľa Johnson, D.E.)	0,60	0,80	0,90	0,85		
applied in calculation	0.50	0.65	0,75	0,80	0,75	0,65

With the values K_c and needed meteorological parametres known, the balance of ground water reserves and the required irrigation water amounts can be determined while maintaining the soil water contents in between the points of decreased availability (Θ_{DAP}) and normal normal field capacity (Θ_{NFC}). We have applied the Agricultural Field Scale Irrigation Requirements Simulation (AFSIRS) model (SMAJSTRLA, 1990) simulating a whole of dynamic processes of infiltration, re-distribution and uptake of water by plants in daily steps. The water reserves are calculated for two strata –irrigated and not irrigated ones. It is assumed that from the irrigated stratum – constituting one half of the entire balanced soil profile – some 70 % of water is used for transpiration and this share may increase, depending on the decrease of water content in the not irrigated stratum during a longer period of draught. In may happen in extreme circumstances that all water is taken up from the irrigated stratum.

Irrigation is applied as soon as the water reserve in the irrigated stratum falls down to the Θ_{DAP}, that has been established as the percentage share of utilisable water capacity (Θ_{UWC}) for a given soil kind and a given crop in course of vegetation period. Producer can set an irrigation dose beforehand or this can be calculated by a computer application so as Θ_{NFC} values be reached. Water reserve can also by replenished only to a Θ_{UWC} value and to operate irrigation with certain soil moisture deficit.

When owing to an abundant precipitation both soil strata become saturated, infiltration beyond active soil strata or surface run-off may occur and water reserves do not further increase.
The AFSIRS model has been intended to process multi-annual series of data on values of potential evapotranspiration and precipitation. It also includes sub-applications to calculate not only basic statistical characteristics, but also surpass curves of monthly and yearly precipitation totals using Weibull distribution as well. Apart from the aforementioned daily values of water reserves in individual strata, infiltration of precipitation, potential and actual evapotranspiration can be produced. These data are suitable to follow the entire course of calculation.
For grape vine the depth of irrigated profile and overall rooting depth were supposed to be of 75 cm and 150 cm. The simulation was conducted for two soil kinds – loamy and sandy soils having the Θ_{UWC} values of 20% vol. and 10% vol. The irrigation requirement was so calculated that the water reserves were replenished up to the required Θ_{NFC} value. In May, June, July, September and October the Θ_{UWC} values of 50%, 60 %, 80%, 70% and 60% respectively were considered to be Θ_{DAP}.

3. MATERIAL

Meteorological data for 10 stations distributed either directly in or in the vicinity of (Malacky, Milhostov) individual viticultural regions were kindly provided by Slovak Hydro-meteorological Institute (SHMÚ), the stations are listed in **Table 2** and their distribution in individual viticultural areas is indicated on **Figure 1**.

Table 2: The list of climatological stations

Name of the station / number of the viticultural region	Abbreviation	Elevation[m]	Latitude [^{o}N]	Longitude [^{o}E]	Precipitation total IV-IX [mm]	ETP IV-IX [mm]
Bratislava Airport / 1	Br	131	48° 10′	17° 12′	305	622
Hurbanovo / 2	Hu	115	47° 52′	18° 12′	307	622
Jaslovské Bohunice /3	JB	176	48° 29′	17° 40′	318	620
Kuchyňa / 1	Ku	206	48° 24′	17° 09′	378	577
Michalovce / 5	Mi	112	48° 45′	21° 57′	386	538
Milhostov / 5	Ml	104	48° 40′	21° 44′	361	556
Piešťany / 1	Pi	165	48° 37′	17° 50′	348	602
Rimavská Sobota / 4	RS	214	48° 22′	20° 01′	363	544
Somotor / 5	So	100	48° 24′	21° 49′	353	554
Žiharec / 2	Zi	111	48° 04′	17° 52′	320	582

Despite of its not having been recommended by World Meteorological Organization (WMO) as a standardised period, data from three decades between 1971 and 2000 have been processed. Our effort was preferably to analyse the two last decades of the previous century as according to our previous research in this time the number of dry months began to increase.

Slovak viticultural regions:

1 Malokarpatská (Malé Karpaty mountains)
2 Juhoslovenská (southern Slovakia)
3 Nitrianska (Nitra)
4 Stredoslovenská (central Slovakia)
5 Východoslovenská (east Slovakia)
6 Tokajská (east Slovakia)

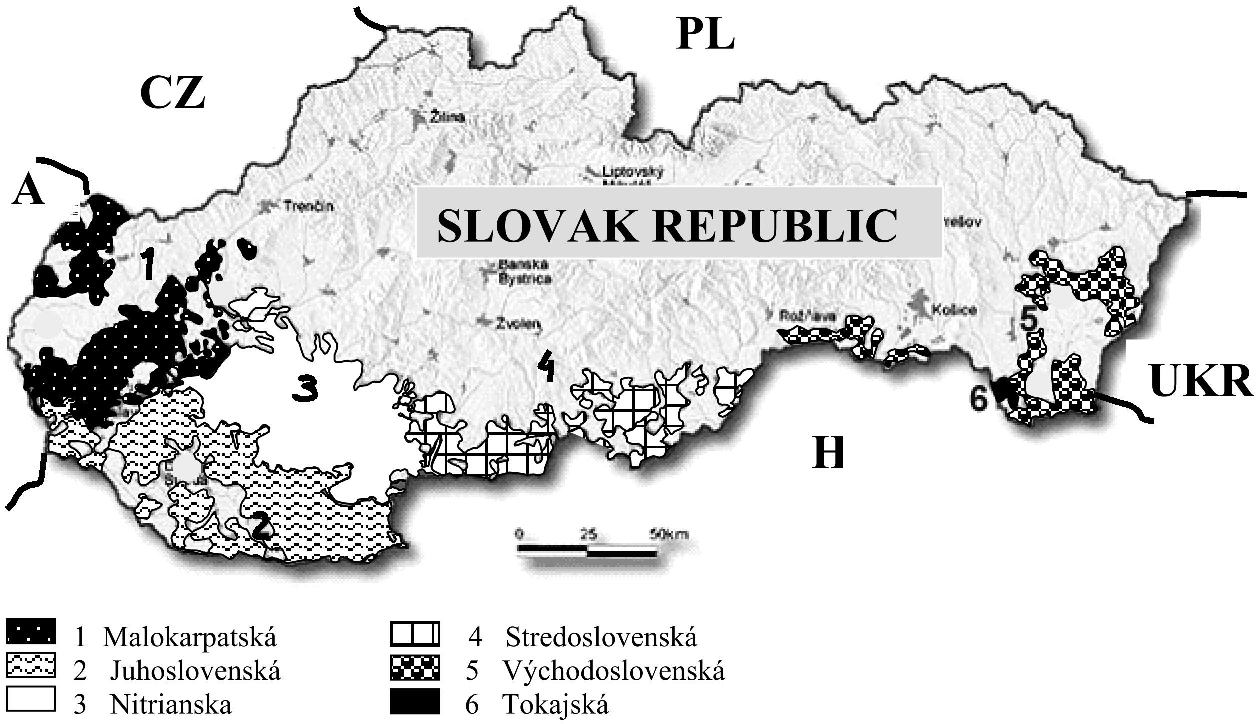

Figure 1 Slovak viticultural regions in 1997

In **Figure 1** there are 6 viticulural regions outlined in Slovakia as larger, integral regions that have been divided into viticultural areas.

A viticultural area should be understood as an integral part of a viticultural region showing similar pedo-climatic conditions and similar assortment of grown grape vine varieties.

The Tokajská viticultural region (6) is a distinct one wherein specific assortment of grape vine varieties has been grown and special vine-making procedures have been followed enabling to produce vines showing unique features.

According to EU classifcation, our viticultural regions have been included in Zone B as divided in 3 categories: B1 - the warmest areas, B2 - less warm areas a B3 – warm areas, e.g. Tokajská region has been included in B1 category.

As it is obvious from **Figure 1**, the distribution of meteorological stations, that maintained complete or almost complete time series of required meteorological parameters from 1971 to 2000, in individual viticultural regions is rather uneven, e.g. in Nitrianska and Tokajská region there are missing at all.

As it will be indicated below, for these regions to calculate irrigation requirement interpolations as associated with precipitation should better be applied.

4. RESULTS AND DISCUSSION

The irrigtaion requirements for individual meteorological stations have been established by the aforementioned method, the results sorted by soil kind are given in **Table 3**. It can be concluded that the irrigation requirements within individual regions have been found different, this in particular applies to Malokarpatská region as it is extended on both sides of Malé Karpaty mountain range. The most demanding for irrigation is Juhoslovenská region and the part of Malokarpatská region adjacent to it. Towards the east the irrigation requirements decrease, similarly in Záhorská Lowland.

The irrigation requiremenst on sandy soils are approximately by 30 mm higher than those on loamy soil and if the saturation of 80 % Θ_{UWC} is to be achieved, the above difference is higher - about 40 mm.

Table 3: The calculated irrigtaion requirement values [mm]

Stations	average		saturation up to 80% Θ_{UWC}	
	loamy soil	sandy soil	loamy soil	sandy soil
Bratislava	81	112	122	160
Jaslovské Bohunice	79	109	117	157
Kuchyňa	43	71	64	104
Piešťany	64	94	94	137
Hurbanovo	81	117	119	160
Žiharec	64	97	97	137
Rimavská Sobota	38	71	53	109
Michalovce	28	56	38	86
Milhostov	38	64	53	97
Somotor	46	71	64	114

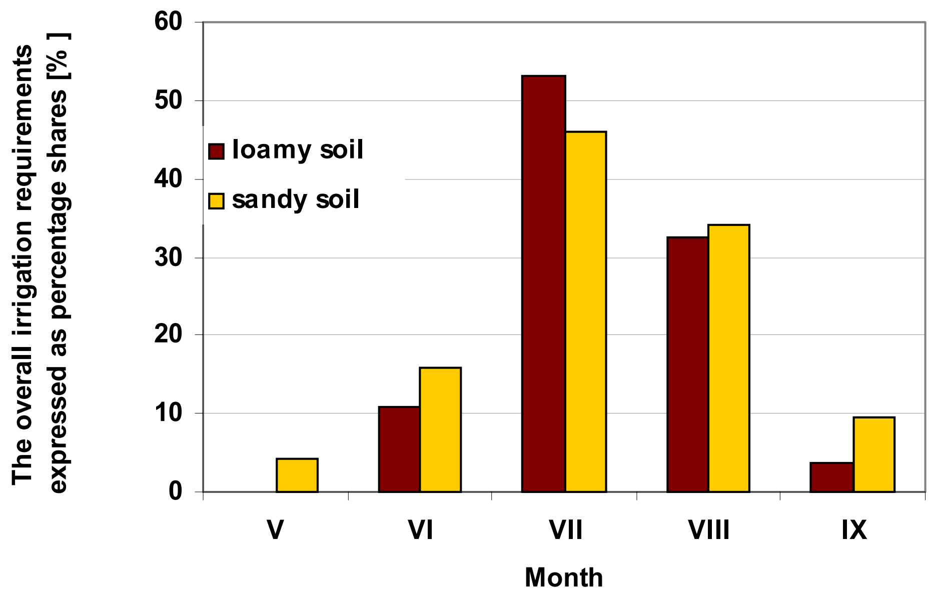

Figure 2: The overall irrigation requirements expressed as percentage shares distributed among individual months

As regards irrigation, July is the most demanding month with almost one half of its requirements. In May irrigation is required only on sandy soils. Despite that towards the end of vegetation period we applied a higher value of K_C as required by some authors, the irigtaion requirements in this time was only insignificant.

The sensitivity of grape vine to water deffficiency in individual growth stages varies. Sufficient water supply from the beginning of fruits development to softening of berries, i.e. prevailingly from July to mid-August.

As within individual climatic regions there use to be more places with different climatic conditions, mainly precipitation, and in some regions there are no climatological stations to provide the parameters necessary to calculate potential evapotranspiration, we have made an effort to determine the association between calculated irrigation requirements and precipitation totals.

There are far more pluviometric stations than those providing complete, long-term climatological data, thus according to the close linear association, illustrated on **Figure 3**, the establishment with certain confidence level of average irrigation requirements for both soil kinds at in fact any location within viticultural regions of Slovakia is possible.

Emanating from regression equations it is obvvious that if a precipotation total increases by 10 mm, the irrigtaion requirements may be reduced by 7 – 8 mm. When the data found between April and September in Nitra by ŠPÁNIK *et al.* (1997), we can gain the irrigation requirement values for loamy and sandy soils of 73 mm and 105 mm respectively.

The precipitation totals for the period 1961 to 1990 does not significantly differ from the period taken into account by us (1971 - 2000) as in the first one the precipitation total for Hurbanovo between May and September is 265 mm and in the latter 269 mm. The problem of draught does not emerge from insufficient precipitation, but from their uneven distribution in course a vegetation period.

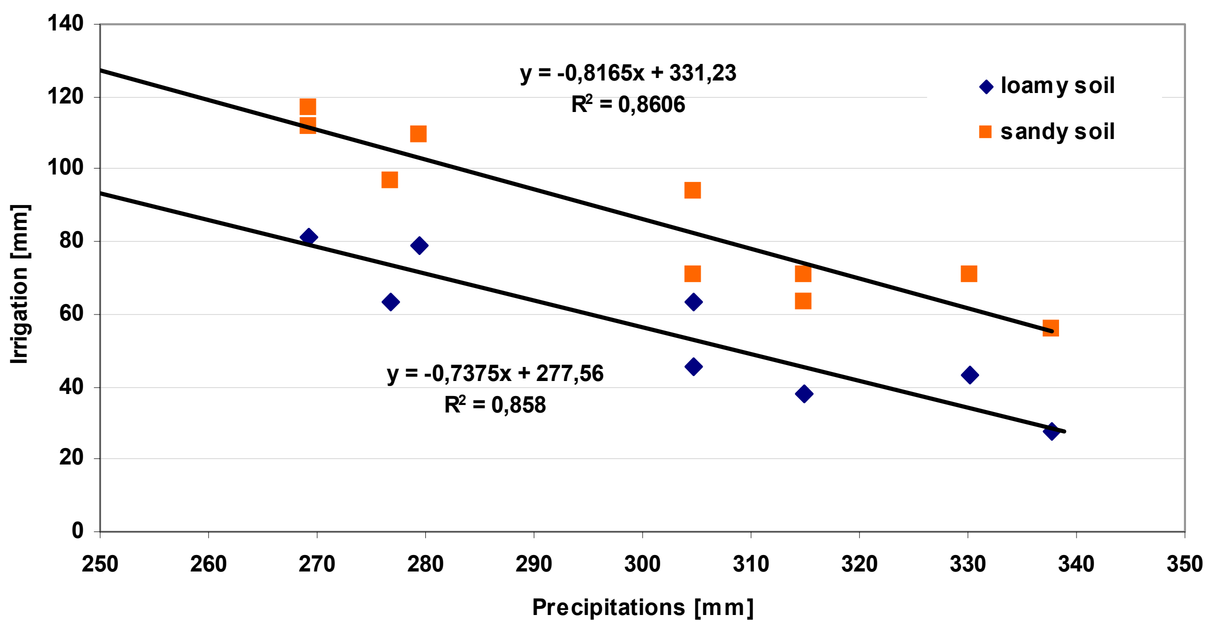

Figure 3: The association of irrigation requirements and precipitation totals for viticultural regions of Slovakia

Similarly regression curves between irrigation requirements with 80 % saturation of Θ_{UWC} and precipitation totals may be drawn. A relatively closed correlation can be seen in **Figure 4**. Contrary to the preceding example the plane curves are a bit steeper; with increasing precipitation by 10 mm the irrigtaion requirements are reduced by approximately the same value, in loamy soils a bit more.

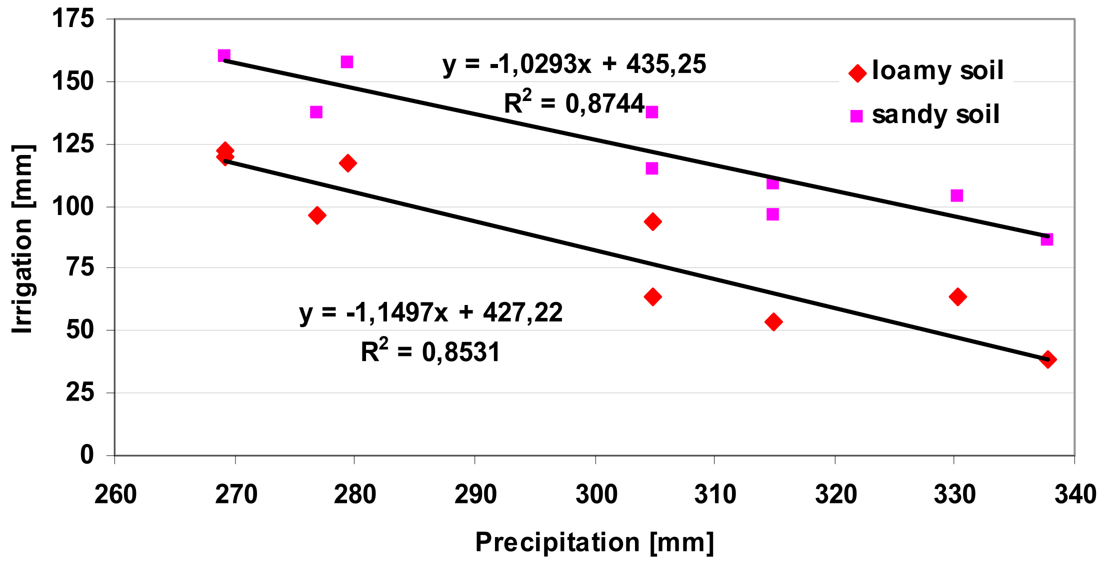

Figure 4: The association of irrigation requirements and precipitation totals for viticultural regions of Slovakia with 80 % saturation of Θ_{UWC}

In practical life we have been very often asked to include certain year into a series of years ordered by their dryness. Such a task is not so simple to fulfil and sometimes it is not possible to draw generalisable conclusions.

The both illustration of two years' irrigation requirements in Hurbanovo (**Figure 5**) and Somotor (**Figure 6**) can bring evidence of it as they represent regions with high demands for moistening irrigation.

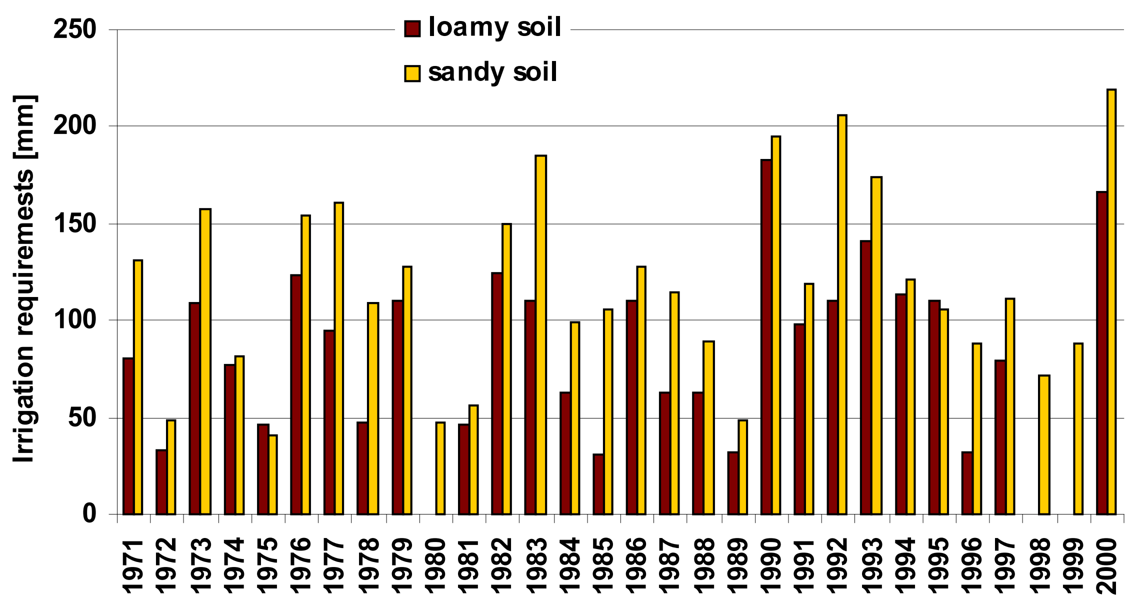

Figure 5: The irrigation requirements in Hurbanovo in individual years between 1971 - 2000

The calculation have been made for both soil kinds and it must be said that significant differences have been found between both stations and soil kinds.
While in Hurbanovo the year 2000 was the driest one for land with sandy soils, that one with loamy soil had the year 1990 as the driest one. contrary to sandy soils those loamy soils are better in equalising bigger extremes in precipitation sums and the duration of precipitationless periods. In years with longer precipitationless periods (1992) the irrigation requirements on sandy soils are almost doubbled in comparison to loamy soils. However, regardless soil kind the irrigation requirements by grape vine in dry years (e.g. 1990 onwards) did not significantly differ.
In Somotor the highest irrigation requirements were in 1992 on both soil kinds, in 1990 the precipitation conditions were totally diferent than those in the western parts of Slovakia. However, a remarkable fact is the growing numerousness of the need to irrigate in course of 1990s not only on sandy, but also on loamy soil, where this need was in course of the recent two decades only sporadic. It is clear that in the driest year the irrigation requirements by grape vine at both sites were almost equal and reached approximately 200 mm.

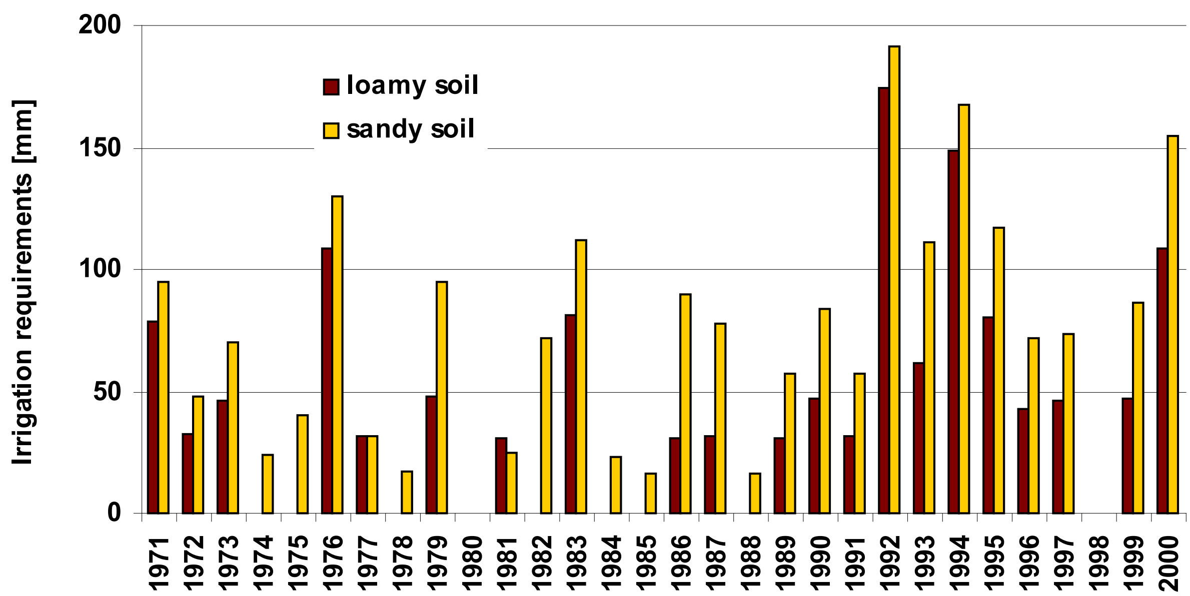

Figure 6: The irrigation requirements in Somotor in individual years between 1971 – 2000

5. CONCLUSION

In the presented paper a new calculation of the irrigation requirements by hypothetical grape-vine stands at climatological stations distributed in individual viticultural regions on the territory of Slovakia has been proposed. The values were established for the period of 1971 and 2000 for both sandy and loamy soils. Using derived regression associations between irrigation requirements and precipitation totals in April to September the calculation of irrigation requirements for those sites where calculations were not carried out, but their precipitation totals are known, can be completed.
Regression associations have been derived also for irrigation requirements with with 80 % saturation of Θ_{UWC}, what corresponds to an apparently dry year.

The irrigation need of any crop depends not only on its species, but also on its variety, eventually rootstock or shape of folias surface, etc. As KRAUS (1976) has indicated, the intensity of transpiration by typical varieties of west Europe was higher than by those from Black Sea region. Varieties may be classified as follows:

* varieties showing high intensity of transpiration: Tramín červený, Burgundské biele, Starovavrinecké, Sauvignon, Rizling rýnsky, Müler Thürgau, Muškát Ottonel
* varieties showing medium intensity of transpiration: Neuburské, Irsay Oliver, Rizling vlašský, Zweigeltrebe, Cabernet Sauvignon, Burgundské modré, Veltlínske zelené
* varieties showing low intensity of transpiration: Leanka biela, Sylvánske zelené, Portugalské modré, Frankovka.

The above shall be taken into account when the aforementioned values are to be applied in irrigation practice, but also the non-inclusion of losses coefficient of a given irrigitation equipment into calculations as well. Despite that the values, which we have calculated, relatively well correspond to those published earlier, our work is important as new methods applicable in our conditions have been verified. At the same time association based on values from ten sites have been determined, that are interpolable and enable to calculate irrigation requirements for sites within any grape-vine region in Slovakia.

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6. LITERATÚRA

ALLEN R.G. et all. (1998): Crop evapotranspiration - Guidelines for computing crop water requirements. FAO Irrigation and drainage paper 56, Rome, ISBN 92-5-104219-5

JOHNSON, D.E. (1993): Effect of irrigation and pruning practices on vine health and fruit quality. ČSN 75 0434: *Potřeba vody pro doplňkovou závlahu* (Water requirements for moistening irrigation). Praha, Český normalizační institut, 32 p.

KOHUT, M.: *Vybrané metody výpočtu evaporace a evapotranspirace* (Selected methods how to calculate evaporation and evapotranspiration), (2003). In.:Rožnovský, J., Litschmann, T. (ed): Seminar "*Mikroklima porostů* ("Micro-climate in stands"), Brno, March 26, 2003, ISBN 80-86690-05-9, pp. 172-186

LITSCHMANN, T., KLEMENTOVÁ, E. (2002): *Spotřeba závlahové vody teplomilnými ovocnými dřevinami* (Irrigation water uptake by thermophilous fruit woody crops). X. poster day with international participation "*Transport vody, chemikálií a energie v systéme pôda – rastlina – atmosféra*" ("Transport of water, chemicals a energy in the system soil - plant - atmosphere"). Bratislava 28.11.2002, ISBN 80-968480-9-7

SMAJSTRLA, A.G. 1990: Agricultural Field Scale Irrigation Requirements Simulation (AFSIRS) Model. IFAS, University of Florida. Technical Manual. Gainesdville FL. 1990, 252 pp.

SNYDER, R.L., ORANG M., MATYAC, S., ECHING, S., (2002): Crop coefficients. Quick Answer ET002, Regents of the university of California, 2002 - INTERNET

SPITZ, P.: *Závlahová potřeba vinice a její stanovení retrospektivní vláhovou bilancí na počítači* (1976) (Irrigation requirements by grape vine and its computerised determination through retrospective water balance). In.: *Závlaha sadov a vinohradov*. (Irrigation of orchards and vine yards). Proceedings from a conference, Znojmo 15.-16.9.1976, VÚZH Bratislava, 1976, pp. 68 - 76.

ŠPÁNIK, F. (1997)a kol: *Aplikovaná agrometeorológia*. (Applied agrometeorology) SPU Nitra, 1997, 194 p., ISBN 80-7137-421-0

Zborník prác Slovenského hydrometeorologického ústavu v Bratislave (1991), (Bulletin of scientific works by Slovak Hydro-meteorological Institute in Bratislava), Vol. 33/I, ALFA, Bratislava 1991, 239 p.