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NEAR SURFACE DETECTION OF DEPTH-SOURCED SALINE WATER, DUNA-TISZA INTERFLUVE

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Abstarct

In the Duna-Tisza Interfluve in Hungary, and mostly in the Duna-valley, the salinization is a great problem for the agriculture. The amelioration of sodic soils, and the protection of saline wetland areas require the knowledge of the source of salt, and the controls and mechanisms of salt distribution. According to hydrogeological research on the area, two principal forces drive subsurface waters (Tóth and Almási, 2001). Deep overpressures due to tectonic compression and gravity at shallow depths. In the Duna-valley – according to our hydraulic studies – both systems discharge in areas of saline lakes and salt effected soils. According to our hypothesis, the high salinity of the lakes and soils is probably related to the highly saline deep flow system. We have tried to prove this hypothesis with the help of chemical and geophysical measurements in the area of Kelemen-szék lake. The chemical results indicate the presence of saline waters below the lake (~3-5000 mg/l) and fresh groundwater to the east (~2-400 mg/l). Resistivity measurements show similar distribution of the systems to 100-120 m depth. These results suggest the presence of deep saline water near the surface and support the deep origin of high salinity.

Keywords: salinization, geophysical survey, wetland

This paper was delivered as presentation on the International Conference on Ecological problems of our days held at Keszthely, on 30 th November, 2006

Összefoglalás

A Duna-Tisza köze területe, és elsősorban a Duna-völgy a szikesedés által erősen érintett terület, ami nagy problémát jelent a mezőgazdaság számára. A szikes talajok javítása elengedhetetlen, valamint a Duna-völgy sós vizes élőhelyeinek védelme is elsődleges feladat. Ez azonban megköveteli a szikesedés eredetének és a sószállítási mechanizmusoknak ismeretét. A területen végzett hidraulikai feldolgozás kimutatta, hogy a felszín alatti vizeket két hajtóerő tartja mozgásban (Tóth and Almási, 2001). A mély, aljzatból induló túlnyomások és a sekély vizeket hajtó gravitáció. A Duna-völgyben – a hidraulikai feldolgozásunk alapján – a két rendszer egyaránt megcsapolódik a szikes tavak, wetlandek, és szikes talajok zónájában. Feltevésünk szerint a felszíni sós jelenségek a mély eredetű, túlnyomásos rendszer magas oldott anyag tartalmú vizének megcsapolódásához köthetőek. Kémiai és geofizikai vizsgálatokkal próbáltuk alátámasztani hipotézisünket. A kémiai eredmények ”sós”, nagy oldott anyag tartalmú víz jelenlétét mutatták ki a tó alatt, tőle K-re pedig ”édesvíz” válik uralkodóvá. A geofizikai ellenállásmérések alátámasztották ezt a térbeli eloszlást 100-120 m-es mélységig. Az eredmények együttesen igazolták a mély, sós víz felszín közeli megjelenését és a szikesedés mély, felszín alatti víz eredetét.

Kulcsszavak: szikesedés, geofizikai felmérés, vizes élőhely

Introduction

The Duna-Tisza Interfluve (DTI) area of the Hungarian Great Plain is one of the most densely populated regions of Hungary (Fig. 1.). The area between the two rivers is rich in groundwater resources. The main activity of the population is agriculture. Unfortunately, the area is not just plagued by droughts but in the last decades by the effect of overpumping as well. The other main problem is salinization. Large parts of the interfluve are covered by salt affected soils, and salinized wetland areas, principally in the valley of the Duna (Duna-valley). Amelioration of the sodic soils and protection of wetland areas are thus essential. These areas are also habitats of rare migratory birds requiring the protection too. These tasks have to be based on the knowledge of the origin of salt, and the controls and mechanism of the salt-transport as well.

In order to solve the problems of salinization intensive research started in the last two centuries (Tessedik, 1804, Balogh, 1840, Sigmond, 1923 etc). The opinions regarding the origin of salt were different. First Kovács (1960) mentioned the subsurface dissolution and transport of the salts to the Duna-valley area. Other researchers have had the same result that the salt is originating from the deep basinfill and transported and distributed by groundwater (Várallyay, 1967). Nevertheless, the now accepted hypothesis of salinization is that shallow groundwater flowing from higher elevations towards the Duna-valley, converges in the deeper pans and evaporates (Molnár and Murvai, 1976; Kuti, 1977). In our study we attempt to find the right answer to the question with a hydrogeological approach in the Duna-valley, in the case of the saline Kelemen-szék Lake.

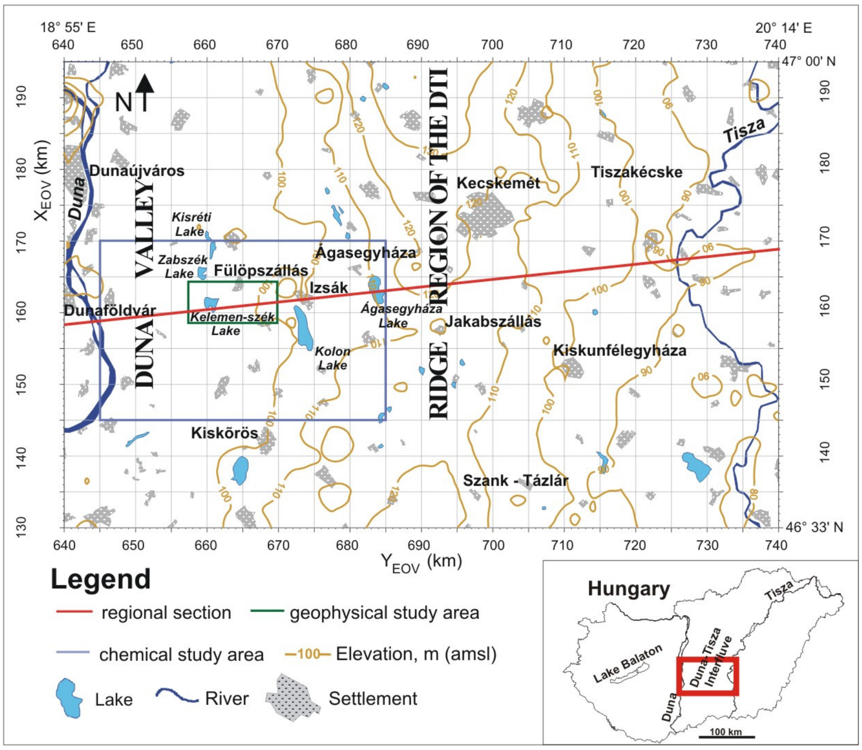

Fig. 1. Research area

Hydrogeological background, results of our former research

In the Duna-Tisza Interfluve, according to a detailed hydraulic study, based on 16000 well-data (Tóth and Almási, 2001) two driving forces are prevalent. Near the surface are situated gravity-driven flow systems, which are perched on deep, over-pressured waters, originating in the Pre-Neogene basinfill. Detailed hydraulic and hydrostratigraphic studies show that the deep-water component approaches the surface in the Duna-valley, where a saline wetland area is found with highly saline lakes (Mádlné Szőnyi et al., 2005, Mádlné Szőnyi and Tóth, 2007) (Fig. 2.). The deep saline water gets close to the surface along tectonic faults and conductive lenses, intercepting the well-conductive aquifer (AF) and the water bearing aquitard layers (AT) (Fig. 3.). According to our hypothesis, the high salt content of the lakes and soils derives from the deep flow system, and thus indicates ascending saline water (TDS (total dissolved solids): 2-40000 mg/l) (Erdélyi, 1989). The more detailed hydraulic results down to 110 m show, that Kelemen-szék lake is situated in the discharge area of the deep system, while the gravity systems are prevalent east of it (Fig.3.) (Mádlné Szőnyi et al., 2005). In the present study we have attempted to verify this hydraulic situation, the connection between the lake and the water of the deep system, and to examine the interrelationship between the two systems close to the surface (100-120 m).

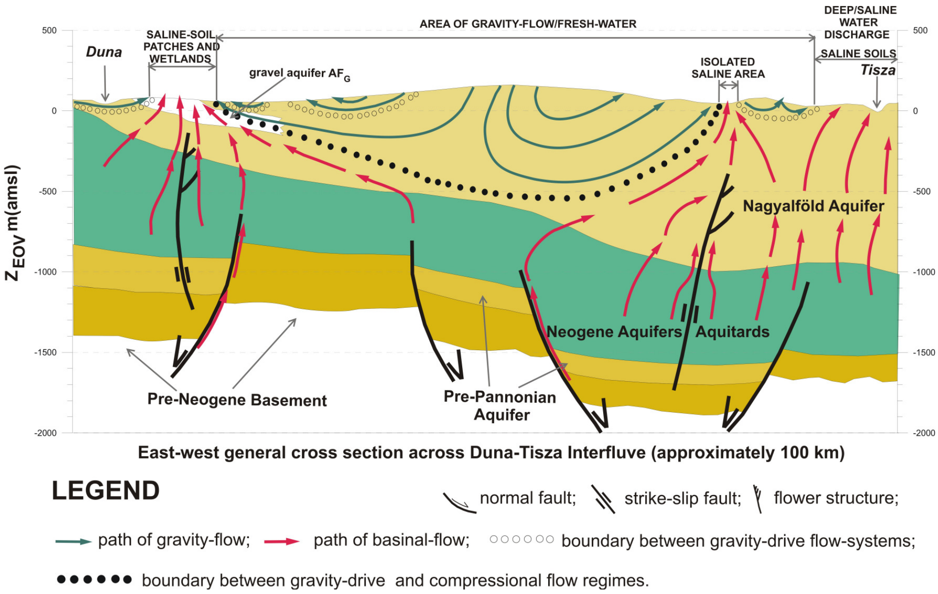

Fig. 2. Schematic hydraulic and hydrostratigraphic cross section of the Duna-Tisza Interfluve (along the regional cross section line shown in figure 1.)

(Mádlné Szőnyi and Tóth, 2007)

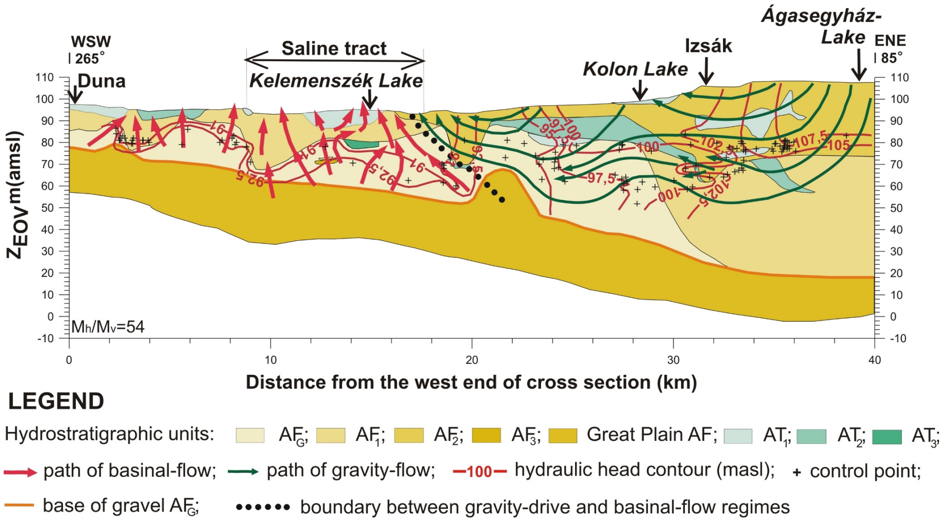

Fig.3. Shallow hydraulic and hydrostratigraphic section (along the regional cross section line, within the chemical study area shown in figure 1.), (Mádlné Szőnyi et al., 2005)

AT:aquitards, AF:aquifers

Applied methods

Identification of waters of the two systems is based on their different chemical composition. The TDS content of the over-pressured system could reach 40000 mg/l, and it has high Cl^- (21000 mg/l) and Na (12000 mg/l) contents as well (Erdélyi, 1989). Although it reaches the surface presumably diluted by shallow groundwater, it can still have higher TDS content than the "fresh" water of the gravity-driven systems. Based on this idea, higher values below the lake, and continuously decreasing TDS values towards east are expected in the groundwater. This distribution could be checked in specific points with examination of the chemical compositions of well waters and spatially by geophysical measurements.

With the help of geophysical resistivity measurements the different salt contents of pore water can be detected, because the measured resistivity includes the characteristic of the rock and the pore water as well. In the study area the geological strata are subhorizontally bedded, so in a given layer local differences of resistivity originate from the chemical difference in groundwater (smaller resistivity values signify higher TDS content). This way we can examine the spatial distribution of the different water types and the presence of a boundary between the two systems. In the course of the investigation electric (VES (Vertical Electric Sounding) measurements, penetration: 100-120 m) and electromagnetic (RMT) (Turberg et al., 1994; Stiefelhageln, 1998), penetration: 18-25 m) methods were also used.

To realize VES measurements, direct current or alternating current of very low frequency is introduced into the ground via two electrodes (A and B). The potential diffence is measured between the other two electrodes (M and N). The geometrical arrangement of the electrodes could be different, but we applied the Schlumberger array, where the distance between MN is less than fifth of the AB distance. The larger the distance between A and B, from the deeper we get information. Knowing the current intensity (I) and the measured potential difference (ΔV) the apparent resistivity (ρ_a) can be calculated by Ohm's law (1). The K factor in Eq. 2. depends on the electrode arrangement, and is called the geometric factor.

$$\rho_a = K \frac{\Delta V}{I} \tag{1}$$

$$K = \pi \frac{(AB/2)^2 - (MN/2)^2}{MN} \tag{2}$$

From the apparent resisitivity values (ρ_a) the subsurface specific resisitivity distribution is calculated by two computer programs: the PISE (from the Geophysical Department of the VI. University of Paris) and the Schlumberger (improved at CHYN). In this way we get the layer thicknesses and resistivity values as functions of the pore water electrolyte conductivity (Erdélyi and Gálfi, 1988).

The other method applied was the electromagnetic measurements with RMT (Radio MagnetoTellurics 12-240 kHz) instrument. This is a further developed version of the very low frequency electromagnetic instrument VLF-R (Müller, 1982). This method works with low frequency transmitter radiowaves and detects the induced electric and magnetic field in the rock media. The VLF-Resistivity (VLF-R) method measures the relation between the horizontal magnetic field with an induction coil and the electric field using two electrodes placed in the ground. This method determines apparent resistivities at the penetration depth of the used transmitter-frequency (Bosch and Müller, 2005). The RMT method is a further developed variant of the VLF-R that works in a lower, 12 – 240 kHz frequency-range. In the course of the investigation three different frequencies are used, which result in different penetrations. At the detection this equipment provides an apparent resisitivity value (in Ωm) and the phase-shift (in degree) between the horizontal, magnetic and the vertical electric field component. These two parameters allowed data interpretation based on magnetotellurics (MT) to calculate specific resistivity-depth-distribution (Fischer et al., 1981). These specific resistivity values allow us to compile cross sections or distinguish between the effects of the rock and the pore water.

Results of the chemical investigation

In the former, detailed investigations (Mádlné Szőnyi and Tóth, 2007) it was shown, that the saline water of the deep system rises close to the surface along faults and highly conductive lenses, where it is diluted by "fresh" water of the gravity driven system. In the course of the chemical study we looked for the presence of this saline water in the shallow groundwater (down to 60-70 m), to indicate connection between the deeper saline waters and the surface salinization. The chemical study was carried out along a cross section of the hydraulic investigations, for the chemical study area shown in figure 1, down to depths of 60-70 m. The TDS and Cl^- contents were used, because they are the most reliable components, and are indicative of the deep system. Within a distance of 2 km on both sides of the cross section all available chemical data from wells were collected, and complemented with our measured field data. The general distribution of the chemistry of groundwater is delineated along the cross section. The values show the presence of two different hydraulic systems with different chemical compositions to a depth of 60-70 m (Fig 4.). The highest values are observed below the lake (TDS: 2540-5750 mg/l, Cl^-:579-1016 mg/l). The concentrations decrease abruptly to the east (TDS: 246-446 mg/l, Cl^-:6-31 mg/l), supporting the hydraulically based hypothesis. This difference can be detected in the different layers, which shows that the change in chemical composition is independent from the lithology. This also proves the effect of the two systems. Below the lake the values are increasing toward the surface, which indicates the increasing effect of evaporation near the surface. The chemical data prove also the presence of an interface between the two systems, in the same place where the hydraulically indicated boundary was drawn.

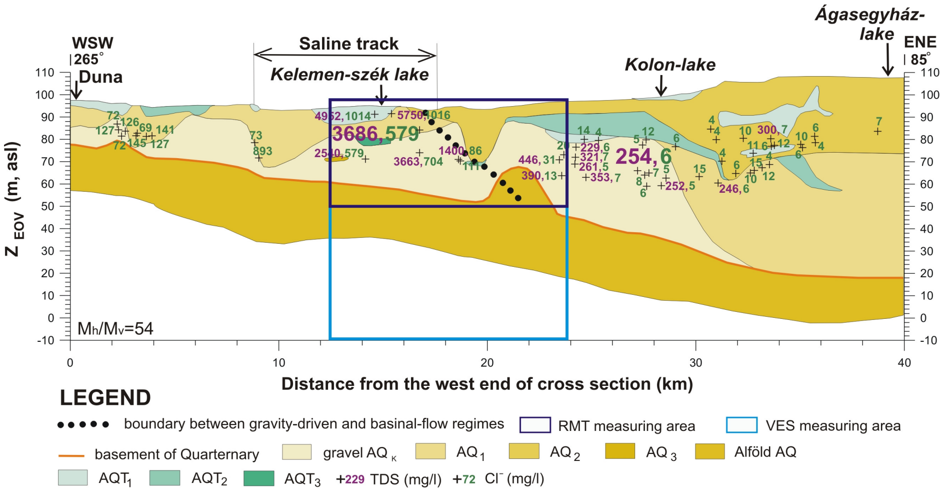

Fig. 4. TDS and Cl^- content of the groundwater

Geophysical results

The geophysical measurements were carried out in the close vicinity of the hydraulic cross section. On figure 4 the bigger quadrangle shows the area and the penetration of the VES, and the smaller area of the RMT measurements. The locations of the measurements are shown in figure 5. The RMT measurements were carried out along a section, while the VES measurements in close vicinity of existing boreholes and wells, where the lithology is known in detail. This way in the course of interpretation it was possible to separate the effect of the lithology and the effect of the pore water more reliably.

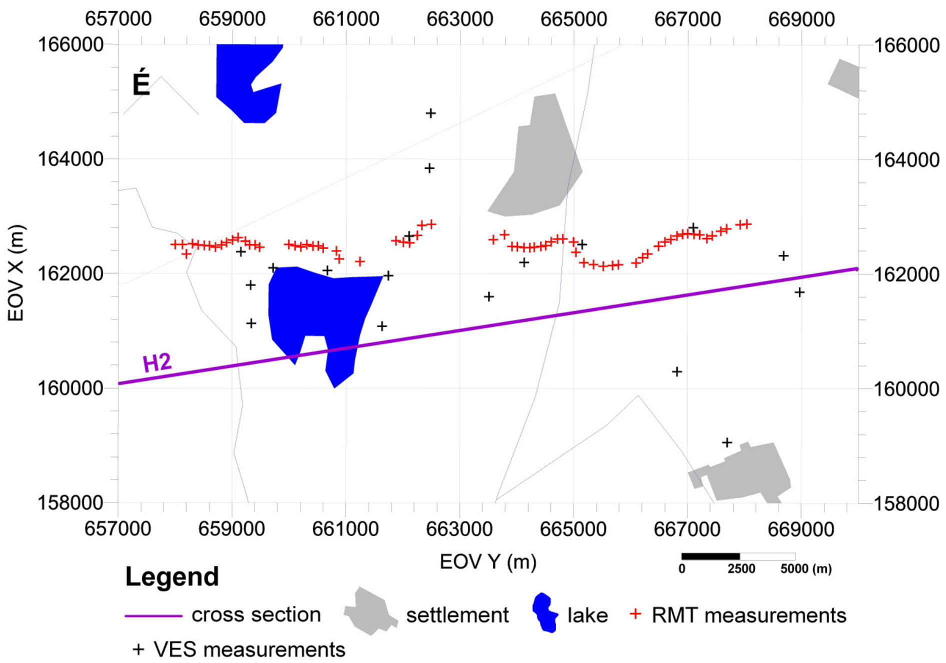

Fig. 5. Area of the geophysical measurements

The measured resisitivity values are represented on the area of the two quadrangles on figure 4 and correlate with the hydrostratigraphy. The hydrostratigraphy was compiled from the boreholes, where the VES measurements where carried out. The different, coloured layers signify different hydrostratigraphic units (Mádlné Szőnyi et al., 2005). The black numbers show the resistivity of the rocks, if these contained with fresh water (2-300 mg/l). These values are known from the literature and are refined with the locally measured K (hydraulic conductivity) values. The distribution of the specific resistivity values are shown by isolines in figure 6, 7, 8. According to the RMT results (red isolines) the measured values are smaller then the fresh water filled values below the lake (20-30 Ωm) (Fig.6.). This distribution is proved till ~ 20 m, in the silt layer above, and in the gravel (the lightest yellow layer) as well. Towards east the measured values increase and reach the black values, thus supporting the hydraulically based hypothesis (Fig.2.). The VES measurements (blue isolines) show the same distribution (Fig.7.). In every layer, west from the supposed boundary of the two systems much smaller resistivity values were measured, than those expected from sediment saturated with fresh water (2-300 mg/l). The biggest differences are in the lightest yellow gravel layer. This deviation can be followed in every layer to a depth of 100 m, which indicates the presence of highly saline groundwater. To the east the resistivity values are continuously increasing and reaching the black values, which means that the salinity of the groundwater is decreasing. Comparing the result of the two different geophysical methods, the distribution of the values agrees well (Fig. 8.). The 30 Ωm transition values shown by both methods could represent the boundary between the “saline” and the “fresh” water. This boundary does not represent a sharp change between the two different water types, rather a gradual transition over a distance of ~2-3 km. This transition was suggested by the chemical and hydraulic results too, and application of the geophysical methods its definition could be improved.

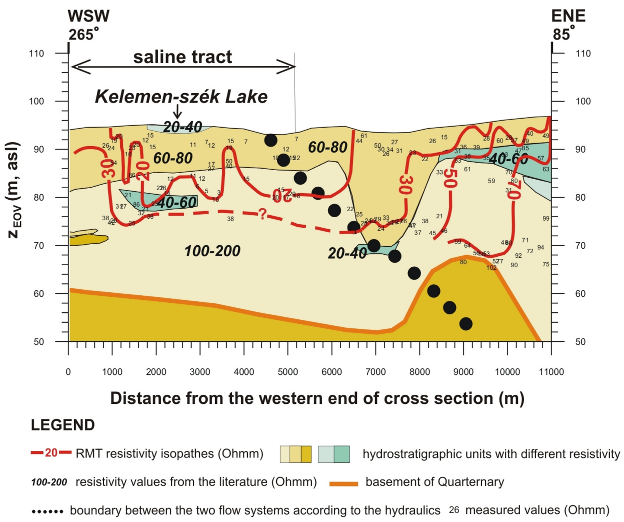

Fig 6. RMT measurements

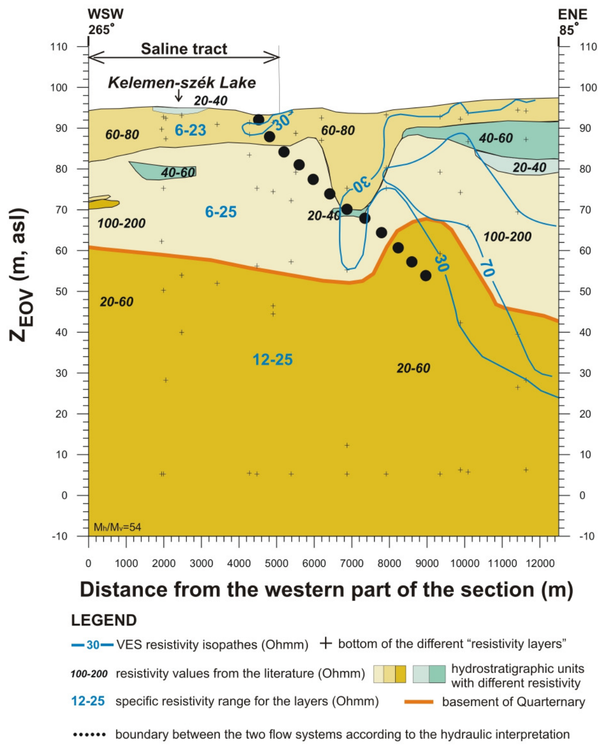

Fig 7. VES interpretation

According to this distribution highly saline water fills the pores in the surroundings of the lake to a depth of 100 m, and “fresh water” of a gravity system dominates the eastern part of the area. In addition, the resistivity measurements support also the presence of an interface between the two water types.

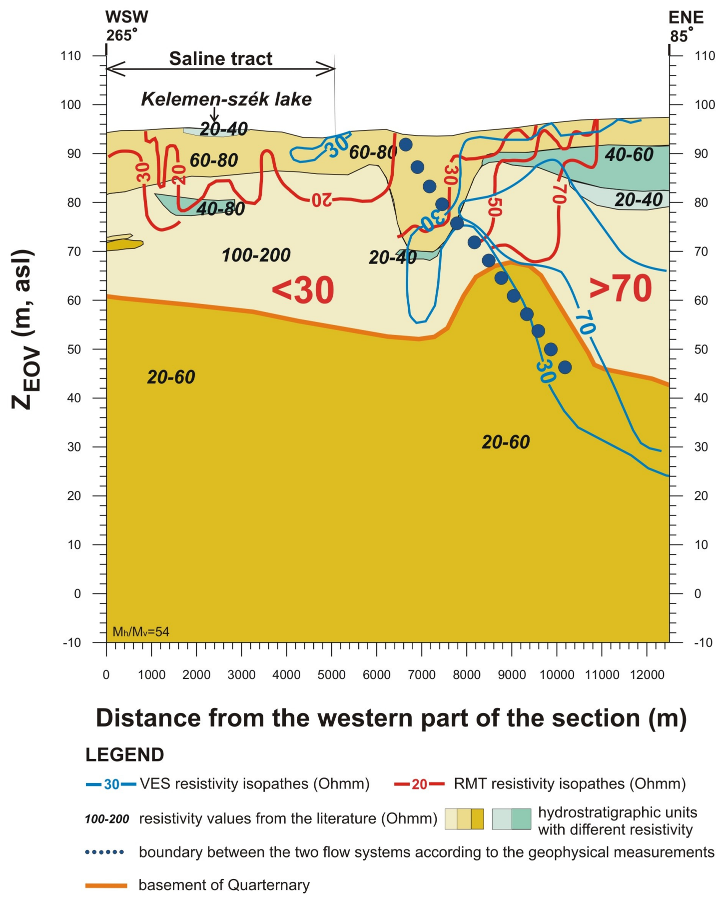

Fig 8. Geophysical results

Conclusion

Knowledge of the origin of salt and salt transport is essential for the amelioration of the sodic soils in salinization plagued areas.

We attempted to find the origin of salt in the Duna-valley, and understand salinization with three different methods. We tried to verify the hydraulic based hypothesis with the help of the interpretation of the chemical data and the geophysical measurements. The three methods provided the same result. The study area is affected by two different groundwater flow system. A deep flow system dominates in the surrounding of the lake, and it rises to the surface. This highly saline water discharges in the lake (presumably diluted by the fresh water), providing the source of salt for the lake and the sodic soils. Towards the east, the “fresh” water of the gravity system is prevalent. The investigations have revealed also the presence of an interface between the two systems.

These results prove the deep origin of the salt and salinization. The study corroborates our former observations concerning the groundwater flow systems of the Duna-Tisza Interfluve. The methods are applicable to and the results useful in further investigations of the area. The results are not only new scientifically, but are relevant also to amelioration of sodic soils, management of thermal water resources of the area, water management and protection of the agricultural environment.

Acknowledgements

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SIMULATION OF LOCAL PLANT TEMPERATURE IN MAIZE AT KESZTHELY AS A RESULT OF GLOBAL CLIMATE MODIFICATION

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Abstract

By applying the various scenarios on global warming we examined the crop temperature in maize at Keszthely with the help of Goudriaan's micro-climate simulation model. Our scenarios contained several ideas with higher warming up beside the domestic downscaling of the IPCC 2007 report (A2 and B2). We found that the temperature in maize at cob level increased by 0.6 °C in Keszthely, compared to the 1961-1990s. The presence of the canopy slightly compensated the rise in plant temperature, even at simulations with rather high warming up. Compensation degree depended on water supply, too. The better water supply brings more intensive development of green surface of plants so provides stronger shadowing effect; this also affected the development of plant temperature.

Key-words: simulation modeling, plant temperature, maize

This paper was delivered as presentation on the International Conference on Ecological problems of our days held at Keszthely, on 30 th November, 2006

Összefoglalás

A globális klímaváltozás helyi hatásának vizsgálata a kukorica növényhőmérsékletének szimulációja alapján

A globális felmelegedésre vonatkozó eltérő szcenáriók alkalmazásával vizsgáltuk a kukorica növényhőmérséklet alakulását Keszthelyen, a Goudriaan féle mikroklíma szimulációs modell felhasználásával. A jövőképeink az IPCC 2007-es jelentésének hazai leskálázása mellett (A2 és B2) néhány magasabb felmelegedésű elképzelést is tartalmaztak. Megállapítottuk, hogy Keszthelyen az elmúlt évtizedben a kukorica cső szinti hőmérséklete eddig 0.6°C-al emelkedett az 1961-90-es évekhez képest. Az állomány jelenléte a növényhőmérséklet növekedését némiképp kompenzálta, még meglehetősen erős felmelegedés szimulációnál is. A kompenzáció mértéke függött a vízellátottságtól is. Jobb vízellátás nagyobb zöldfelület képzéssel és ezzel erőteljesebb árnyékoló hatással jár együtt, mely a növényhőmérséklet alakulását is befolyásolta.

Introduction

The role of plant temperature is paramount in physiological processes since the speed of biochemical reactions is determined by the temporary value thereof. Plant temperature depends on the ambient air temperature due to the localised nature of plants. At the beginning the researchers approximated the relationship between air temperature and the different physiological processes by the temperature optimum curve

(*Larcher* 1980). It is a special feature of the function that the shape of the curve is the same at all physiological processes, only the actual temperatures change by plant species, breeds, development stage, etc. The observations pertaining to plant temperature has started much later due to the cumbersome nature of measurement of the element. In the case of plants the plant and air temperatures can only be separated in theory since these elements determine and depend on each other. Plant temperature – contrary to the body temperature of the higher living beings – is controlled by the outer air temperature in a way that the plant cools itself through evaporation so long as its surface temperature goes close to or below the air temperature (*Anda* 1993a). Stress situation (for example lack of water) could cause that plant temperature exceeds air temperature, which, however, always means damage of physiological processes (*Jackson et al.* 1981). According to the Van't Hoff's rule the intensity of the individual physiological processes from the commencement to the highest level thereof (between the basic and the optimum temperature) doubles or trebles with an increase in air temperature by 10 °C, depending on the nature of the physiological process. Production of dry matter in plants is determined by the difference between the two basic physiological processes, photosynthesis and respiration. At increasing air and plant temperature the intensity of photosynthesis rises to a certain extent – to the optimum temperature –, but the intensity of respiration rises more steeply than photosynthesis in the same temperature range, therefore the increase in production of dry matter deriving from the difference between the two physiological processes will be higher at optimum temperature and more moderate at higher outer temperature.

In Hungary there have been investigations in the Agrometeorological Research Station of Keszthely for decades in order to measure and use in practice (determining the time of irrigation) of plant temperature (*Anda* 1993b, 2002; *Anda and Ligetvári* 1991, 1993). The examinations covered many plant species, but the majority of the measurements were performed on maize (*Anda 2001a, 2001b; Anda and Decsi* 2001).

In the course of the past decades the research of special microclimate and canopy climate has shown significant developments whose outcome was that the theoretical models simulating physical processes gained ground beside the formerly prevailing empirical approaches. The model is a simplified counterpart of an existing system (e.g. a plant or canopy), which is able to emulate the behaviour of the more complex real system. The model also provides opportunity to examine one selected element of the system and not in itself but the behaviour is embedded in the real system and showed in a complex way. In this observation we chose this latter possibility, and we analysed plant temperatures on the basis of the latest scenarios of IPCC 2007 as well as the downscaled ones to Hungary (*Bartholy et al.* 2007). The model applied by us was the PC-executable version of the newer version (*Goudriaan és van Laar* 1994) of the CMSM (Crop Microclimate Simulation Model) by *Goudriaan* (1977).

Material and Methods

Input data and parameters derive from the Agrometeorological Research Station of Keszthely (46°44'N; 17°14'E; 114.2 m above sea level). Input meteorological elements were provided by the local automatic climate station equipped by Eppley pyranometer. Similarly to the meteorological inputs, we used the principle of analogy in the case of the input plant data of the given scenario. At the input plant data we searched for a year – July – that was analogous with the weather to be simulated, where the data on maize and soil moisture were the same or almost the same as the values of the year to be simulated. For this we had an about 30-year data series for medium early maturity maize.

The model inputs are site- and plant-specific values (plant height, leaf density in different layers), soil characteristics and hourly meteorological data (air temperature, global radiation, relative humidity, soil surface temperatures at 24.00 hours), which were transformed from the standard measurement level (Agrometeorological Research Station of Keszthely) to the reference level required by the model. The leaf area and its density were measured in the field on 10 sample plants weekly, using a LI-3000A type leaf area meter.

The soil moisture content in the upper 1 m was also measured in the field gravimetrically at 10 cm intervals every 10 days. The actual soil water content was expressed in terms of soil water potential. The physical properties of the Ramann type brown forest soil (heat capacity, heat conductivity, etc.) were determined at the beginning of the investigations. More details on plant and other data samples see in publication of *Anda* (2006).

The basic of the model assumption is the calculation of energy distribution in the canopy after the radiation reflection and transmission processes (*Goudriaan* and *van Laar* 1994):

$$0 = Rn - M - Q_H - \lambda E \qquad (1)$$

where Rn: net radiation [W m^{-2}]

M: metabolic storage [W m^{-2}]

Q_H: sensible heat flux [W m^{-2}]

λE: latent heat flux [W m^{-2}]

The sensible heat flux (Q_{Hi}) in the i layer is:

$$Q_{H\,i} = \rho c_p \frac{T_{ci} - T_{ai}}{r_{aHi}}, \tag{2}$$

where T_{ai}: air temperature in the i layer [K]

T_{ci}: canopy temperature in the i layer [K]

r_{aHi} : aerodynamic resistance for sensible heat transfer in the i layer [s m^{-1}].

ρ and cp: air density and specific heat of the air, respectively.

The latent heat flux (λE_i) in the i layer can be calculated as follows:

$$\lambda E_i = \rho c_{p(} \{e_s (T_{ci} - e_s)\} / [\gamma (r_{awi} + r_{ci})] \tag{3}$$

where $e_s\,(T_{ci}) - e_i$: difference between saturation vapour concentration at plant temperature and actual vapour concentration [m^3 m^{-3}]

r_{awi}: aerodynamic resistance for water vapour transfer in the i layer [s m^{-1}]

r_{ci}: crop resistance in the i layer [s m^{-1}].

After calculating the sensible and latent heat, the crop temperature (T_c) in the i layer was estimated as:

$$T_{c,i} = T_{a,i} + \left(Q_{H\,i} - Q_{H\,i-1}\right) r_{H,i} \,/\, \rho c_p \tag{4}$$

where $r_{H,i}$: value characteristic of sensible heat resistance in the i layer [s m^{-1}] when i =1 (Ta_{i-1}) is the air temperature for the reference level.

For evaluating the results of the model runs we used paired t-test that was performed by the free version of STATA 5.0 (1996) program package. The process reduces the two-sample t-test to a one-sample test since there is no possibility of repetition (so of calculation of standard deviation) at the model runs. The test compares the mean value of the sample to an expected mean value. According to the null hypothesis if the mean value of the differences is 0 then the two samples are statistically the same. If the mean value of the differences is not 0 then the two samples are significantly different. The significance level was fixed at 5% in the course of the process.

Before applying the *Goudriaan* model in the present work, the validation of air temperature was carried out locally by *Anda et al.* (2001). The observed air temperature used in the validation of the model was collected in the field. To validate the model the root mean square deviation (RMSD) of a number of pairs (n) of simulated (S) and observed (O) elements was applied:

$$RMSD = \left\{\left[\Sigma (O - S)^2\right] / n\right\}^{0.5} \qquad (5)$$

The RMSD is one of the best overall measures of model performance (*Willmott,* 1982). More details see in publication of *Anda* (2006).

The applied scenarios

The meteorological bases (the control – first scenario) of the different scenarios – similarly to the bases of the scenarios presented in the IPCC 2007 report – were provided by the mean values of years 1961-1990 measures at Keszthely. At the control run we used the CO_2 concentration measures performed in the 1980s as well as the background concentration values of K-puszta and Hegyhátsál (*Haszpra* 2007) in order to determine the input CO_2 concentration. Finally we determined the CO_2

concentration of the basic run as 340 ppm. *Haszpra* (2007) fixed the Hungarian value for 1981 as 343 ppm.

The second scenario is to represent the changes of the close past on the basis of the data of the decade between 1997 and 2006. According to the last climate normal, in Keszthely in summer the air temperature is significantly higher by 0.6 °C than the monthly average of Julies of the 1901-2000 data series (*Kocsis* and *Anda* 2006a). Though it cannot be statistically justified, the accumulated quantity of precipitation of July has decreased by about 10-15% in Keszthely (*Kocsis* and *Anda* 2006b, *Kocsis* and *Anda* 2005). We estimated the outer CO_2 concentration to 380 ppm on the basis of the data of the background pollution.

The third scenario is to represent the impacts of the rising ambient CO_2 concentration in quantitative terms, therefore we doubled only the CO_2 gas concentration out of the input data of basic run (760 ppm), and the meteorological inputs remained the same. With this we localised the date of the expected change to 2070-2100.

In the further scenarios – beside doubling the current CO2 level (760 ppm) – we gradually rose the air temperature values compared to the basic run (1961-1990), and together with this we also modified the precipitation. The fourth scenario – on the basis of the B2 scenario of the IPCC 2007 Assessment Report – contained the summer values pertaining to Keszthely of the meteorological elements downscaled and mapped to Hungary by *Bartholy et al.* (2007) forecast to the period of 2070-2100. In this scenario the summer average temperature in Keszthely will rise by 3.8 °C, together with an about 15% decrease in precipitation. The fifth scenario used the summer data of the A2 IPCC-SRES (2000) scenario, downscaled to Hungary by the above-mentioned method, which calculates upon a stronger warming up than the former one (+4.8 °C). There is a 25% decrease in precipitation associated to this temperature rise. We note here that standard deviation is rather high at both scenarios (±15%); this implies strong uncertainty.

In the sixth scenario we increased the average air temperature by 6.0 °C, together with a 25% decrease in precipitation. This 6 °C rise is close to the value of the upper limit value (6.4 °C, annual average) in the IPCC Fourth Assessment Report (2007). This value is the result of the global level prognosis that can be higher in Hungary according to *Mika* (2007). Keeping this in view, in the last two scenarios we performed a further increase in the degree of warming up, by involving the 1.4 times product of the upper temperature rise (6.4 °C) pertaining to Hungary (9 °C). Since we knew the uncertainty of precipitation forecasts, we associated two types of precipitation supply to the 9 °C warming up; the seventh scenario assumes almost no change in precipitation (-10%), while the eighth scenario calculates upon a more significant drying (30% precipitation decrease). The comparison of these latter two scenarios later provided opportunity to quantify the impacts of the different precipitation supplies on plants. Markings of the individual scenarios are summarised in *Table 1*.

Results and Discussion

Vertical distribution of plant temperatures based on 3 measurement levels

First we illustrate the simulation results pertaining to plant temperature at three levels: at 0.38 m above the soil, at 1 m in the cob level and at 1.61 m above the leaves, by scenarios, with two solar positions (at low and high angles of entry) (*Figure 1*). For a better overview, we placed the individual scenarios on the vertical axle.

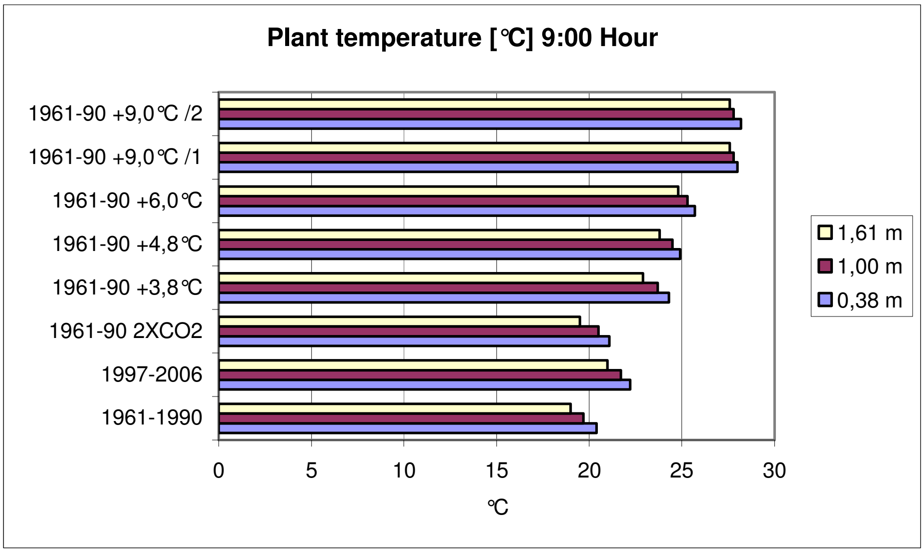

Figure 1 Development of plant temperature by scenarios at low solar position, at the 3 different plant heights simulated by the model: at 0.38 m, 1 m and 1.61 m (appearance of upper leaf levels)

The figure shows that the differences of the values of the individual levels follow the same tendencies depending on plant height in the case of the same scenario and at low angle of entry. Plant temperature is the highest at the level being closest to the soil, irrespective of the scenario; it is followed by the cob level, then temperature is the lowest at the upmost leaf levels. The tendency does not even change at high solar position, only the absolute values of plant temperature rise compared to the values measured in morning hours (*Figure 2*).

As a tendency, the values pertaining to the different levels were more expressive at lower plant temperatures (even at cooler weather simulation), irrespective of the solar position. The stronger the warming up is, the less and less differences in temperature among the individual plant height levels are. The likely reason for this is the stronger evaporation demand due to the higher air temperature whose satisfaction can only be with appropriate water supply. This phenomenon was obvious in the case of the scenarios with warming up above 6 °C, and it was characteristic of both solar positions.

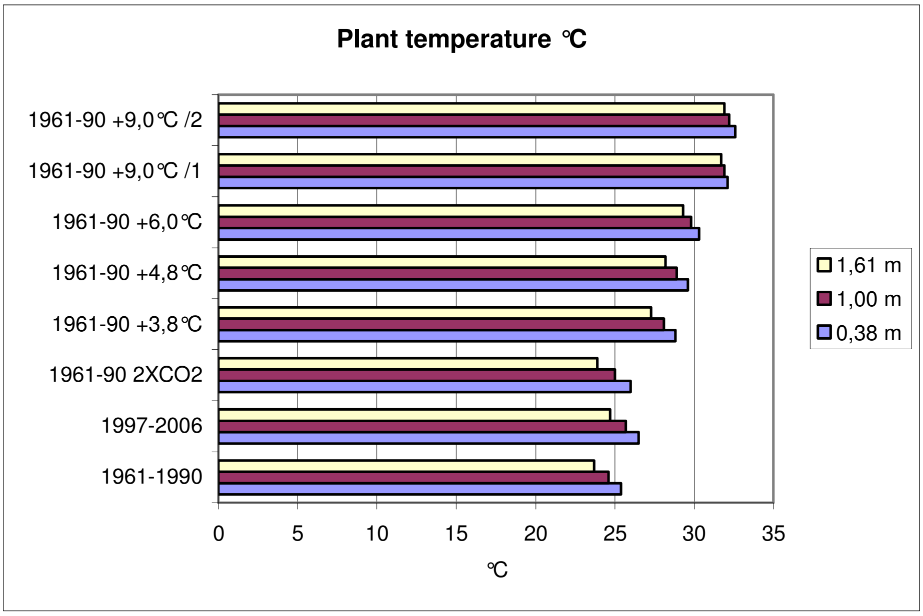

Figure 2 Development of plant temperature by scenarios at high solar position, at the 3 different plant height simulated by the model: at 0.38 m, 1 m and 1.61 m (appearance of upper leaf levels)

Development of plant temperature at cob level

Hereafter we summarise our simulation results to the cob level (1 m from the soil surface), which is the location of the most intensive physiological processes. In the course of the investigation we present the entire daily changes together with the development of plant temperature of night hours; it is a new approach.

In the case of the medium maturity hybrid we used the cob level of the maize was located at the height of 1 m from the soil surface (average of many years), and it did not significantly depend on the year itself. In drier years when the average height of the plants were smaller by 10-20 cm, the cobs were at a bit lower position, though the difference was up to 10-15 cm, similarly to the case of plant height. Based on the 30-year observation data series, the cob level of 1 m above soil surface is advantageous since this difference coincides with one of the locations of the model providing simulation results.

Plant temperature measured at cob level showed moderate rise when doubling the CO_2 concentration; it showed a significant increase of 0.2 °C (daily average) being independent from times of day (*Table 2*). It is in connection with the effect of the risen CO_2 concentration that narrows the stomata and lessens evaporation; it results in a slight increase in plant temperature due to the lack of plant cooling.

Table 1 Basic data of statistical analyses relating to the differences of the daily averages of plant temperature at cob level. Average means the daily average calculated by the model. **We highlighted those p values of the t-test in bold that represent significant difference at level of at least 5%.** At the compared scenarios we used ***bold and italic letters for the basic run***.

Scenario pairs	average [°C]	calculated p value of t-test	standard error
A=basic	21.325		
B	21.89583	**0.0059**	0.1881912
C	21.55833	**0.0000**	0.0516632
D	25.05417	**0.0000**	0.0373387
E	26.00417	**0.0000**	0.0503536
F	27.05	**0.0000**	0.0828063
G	29.425	**0.0000**	0.1290995
H	29.79167	**0.0000**	0.1270723
G=basic	29.425		
H	29.79167	**0.0000**	0.1270723
D=basic	25.05417		
E	26.00417	**0.0000**	0.0324149
F=basic	27.05		
G	29.425	**0.0000**	0.0836768
H	29.79167	**0.0000**	0.0473641

The cob level plant temperature in the past decade – similarly to the air temperature – rose significantly, by 0.6 (daily average), but this difference compared to the basic run (1961-1990) – contrary to the cob level canopy inside air temperature – was daily various by nature (*Figure 3*). From the second half of the night to a very high solar position the rise of plant temperature is significant, between 1 and 1.5 °C (hourly average). The direction of the difference between the temperatures of the two scenarios reversed – in the period with the highest solar position to a lesser extent, late afternoon to a larger extent – and its degree was stabilised between -0.2 and -0.7 °C. Finally, common handling of the values of periods with different solar positions resulted in the daily average plant temperature increase of 0.6 °C. We did not experience such a variety by times of day as we compared the other scenarios to the values of the basic run of 1960-1990. When we measured at the other scenarios, the degrees of the differences compared to the run of 1961-1990 proved as constant independently from the time of day.

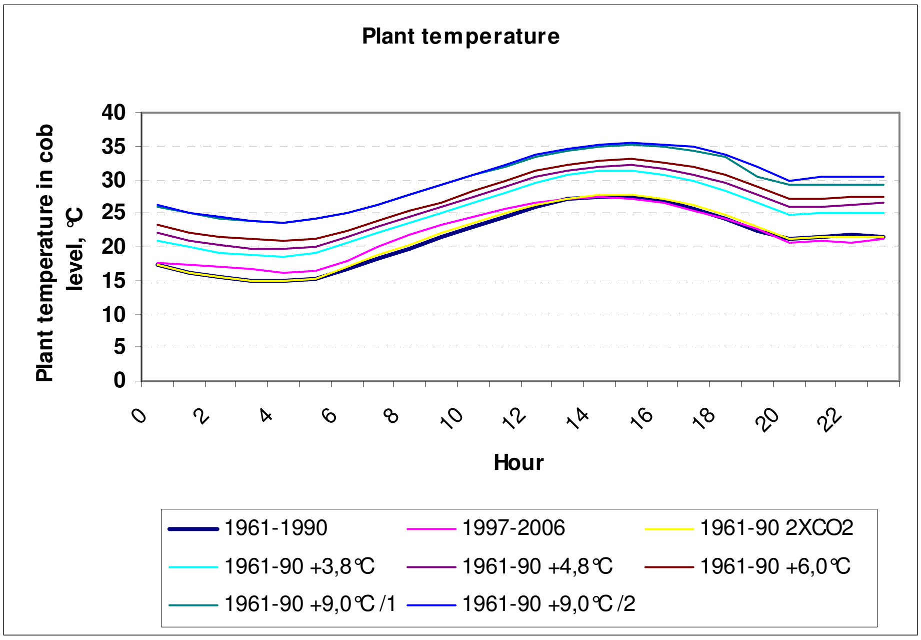

Figure 3 Development of plant temperature simulated to cob level on an average day of July

The rise in plant temperature determined for the downscaling of A2 and B2 scenarios to Hungary did not reach the value of the outer warming up simulated to the run, namely the plant temperature compensating effect of the canopy can be caught. In the case of lower simulated warming up the degree of compensation is lower, only a couple of tenth °C. A2 scenario brought the psychological breakthrough after which – with simulating a warming up of higher degree (from 6 °C up) – the plant temperature compensating effect worked but it was significantly reduced. The effect of the presence of the canopy that mitigates the increase in inside plant temperature compared to the increase in outer temperature emerged even in the case of the last two scenarios, namely depending on water supply. It was 0.9 °C at the scenario with better precipitation supply, and only about the half of it, 0.5 °C in the case of the drier treatment.

Except for the scenario pertaining to the past decade and for the one containing double CO_2 concentration, in the case of all the other runs the time of the development of the highest plant temperature changed, it changed to 3 pm from the former 2 pm. It is not a favourable tendency in itself, and mainly not because the period of the higher plant temperature became longer by one hour. During the afternoon – even under normal conditions – plant temperature frequently exceeds the temperature range favourable for the plant, so its extension increases the presence of the temperature higher than optimum; this certainly affects the production of the plant.

The values of the cob level plant temperature calculated by different scenarios compared to the values of the basic run; the two IPCC scenarios compared to each other; as well as the plant temperatures of both treatments with increased temperatures of 9 °C compared to the scenario with warming up of 6 °C – these all represented slight difference but significant at level of 5% at least. (see Table 2).

Prasad et al. (2006) earlier experienced that the negative effect of the increased plant temperature emerged mainly at the reproduction processes, which were not brought into the focus by the researcher till then. Our results may provide some new information to this topic.

Conclusions

On the basis of the simulation analysis performed to Keszthely it can be asserted that warming up increases plant temperature, but not to the same extent as the outer air temperature rises. The compensating effect of the canopy worked even in the case of serious temperature increase, but the degree thereof was also depending on water supply. The optimum plant temperature of maize is about 23-24 °C, and according to the local measurements performed around noon in Keszthely in July, the actual canopy temperature has exceeded this value several times (*Anda* 2001). The only chance of protection is to provide cooling medium and additional water supply for the plants; this supposes the re-consideration of the former irrigation practice.

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Local scale EM geophysical survey to estimate hydrogeological parameters related to environmental problems

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Abstract

Hydrogeologists need to know the heterogeneous distribution of hydraulic conductivity in the field to protect aquifers against contamination. This parameter can be obtained with direct methods, with drillings and pumping tests, but indirect methods, surface geophysical survey can help to locate a limited numbers of boreholes and put them on the right places. The Radiomagnetotelluric (RMT) geophysical method was developed at CHYN (University of Neuchatel) in the last years to investigate the most permeable areas in loose sediments and fractured rocks. Two men crew can achieve hundreds of vertical frequency soundings a day, map hidden geological structures and obtain indirect estimation of hydraulic conductivity. Hungarian examples are presented.

Introduction

In the most cases contamination are happened in a small scale, like leakage in landfills and hydrogeologists can only predict the consequences of this contamination if they know the heterogeneous distribution of the field of hydraulic conductivities. This parameter

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determines the flow velocity and contaminant transport according to Darcy's Law.

With direct methods, drillings and pumping tests, it is possible to obtain the permeability of aquifer, to prepare potentiometric surface maps and understand the flow field in the aquifer. However direct methods are time consuming and expensive. Surface geophysical survey, an indirect method, can help to get a good conception about the geological structures and about hydraulic conductivities. There exist several geophysical methods for underground investigation, but for local scale survey a new electromagnetic method was developed and experimented: the Radiomagnetotellurics. This method is a fast and reliable method to obtain information in a very local scale and help to delimit with sharp contours the contact of geological boundaries, locate buried river channels and find the most fractured zones in hard rocks.

Basic principles about Radiomagnetotellurics

Since the 1980s, the Centre of Hydrogeology at the University of Neuchatel (CHYN) has concentrated on the application and development of electromagnetic methods and equipment. These methods appeared to have the potential of being appropriate for investigating heterogeneous carbonate rocks and structures in loose sediments. Instead of measuring a medium galvanic resistivity as a result of an electric current injected into the ground (geoelectrics), EM methods measure electric and magnetic fields of the ground, that are created by induction from external, natural or artificial EM fields.

The Very Low Frequency (VLF method) was mainly developed for mineral exploration (Paal 1965). It uses radio-signals emitted by terrestrial transmitters distributed all around the world in the frequency range from 3 to 30 kHz. The VLF method measures the earth's electromagnetic (EM) response induced by the EM fields emitted from these transmitters. The VLF-Resistivity (VLF-R) method measures the relation between the horizontal magnetic field with an induction coil and the electric field using two electrodes placed in the ground. This method determines apparent resistivities at the penetration depth of the used transmitter-frequency. For further theoretical details, the reader is referred to (Bosch & Müller 2005).

In mineral prospecting, the requirements on the sensitivity and resolution of VLF devices are not very high because the observed anomalies are very strong and the investigated targets are large. However, the principles of this method provided the possibility of rapid data acquisition and survey at a local scale. Consequently, electromagnetic methods have been adapted for engineering and environmental surveys and applied to hydrogeological investigations (Palacky et al. 1981; Meyer de Stadelhofen 1991; McNeill 1994).

Since electromagnetic methods appeared to have the potential to fulfil the needed requirements for karst research, an initial approach was done by the construction of a Very Low Frequency-Resistivity (VLF-R) prototype equipment (Müller 1982a; Müller 1982b), that works in the 12 – 24 kHz frequency-range. A magnetic induction coil with a diameter of 40 cm was used to measure the local horizontal magnetic field component H_Y. With a pair of Al-electrodes placed into the ground the horizontal, secondary electric field component E_X is measured. The signal-to-noise-ratio of the measured values is inversely proportional to the electrode spacing. An electrode spacing of 5 m was ascertained as a sufficient compromise between resolution and signal quality. For one polarization direction, this equipment provided from the measured values both apparent resisitivity ρ_a in Ωm and phase-shift Ψ in degree between the horizontal, magnetic and electric field component depending on the transmitter frequency. These two parameters allowed data interpretation based on magnetotellurics (MT) to calculate specific resistivity-depth-distribution (Fischer et al. 1981). With different frequencies and a fixed electrode spacing of 5 m VLF-R resistivity soundings are carried out several orders of magnitude faster, than with traditional geoelectric soundings using electrode-spacing variation. Moreover, to the increased measurement speed, the VLF-R significantly enhanced the horizontal resolution for vertical structures as fractures and faults. The vertical resolution of VLF-R was limited due to the small frequency range. Investigation depths for the frequency-range used and the typical electric resistivities of karstified and massive limestones of the Swiss Jura Mountains (100 to 3000 Ωm) vary between 40 m and 200 m. Consequently, the VLF-R method could detect major faults and fractures, but could not separate horizontal layers at very shallow depths. However, the presence of electrically conductive overburden (some tenth of Ωm) reduces the investigation depth, it remained to excessive for very shallow depths investigation. A device extended to the Low Frequency range (LF) was subsequently constructed. This device works at between 12 and 240 kHz and was called RMT. The penetration depths of the RMT device, varies between 10 to 200 m in karstified and massive limestone. In sedimentary environments, with their significantly lower electric resistivities, the RMT also provides detailed information in the first 30-50 m depth. The apparatus has been successfully applied to a variety of environmental, engineering and academic investigations in karstified, fissured and porous media. Compared to geoelectrics, RMT significantly increased the speed for carrying out resistivity soundings. Two persons can perform at least 150 soundings per day. Thus, the method offers the possibility of covering large areas (Fig 1).

According to the calculated true resistivity we propose an approximation, which correlate resistivities and hydraulic conductivity. This correlation is obtained from about 70 pumping test on different geological settings in loose sediments (Fig. 2).

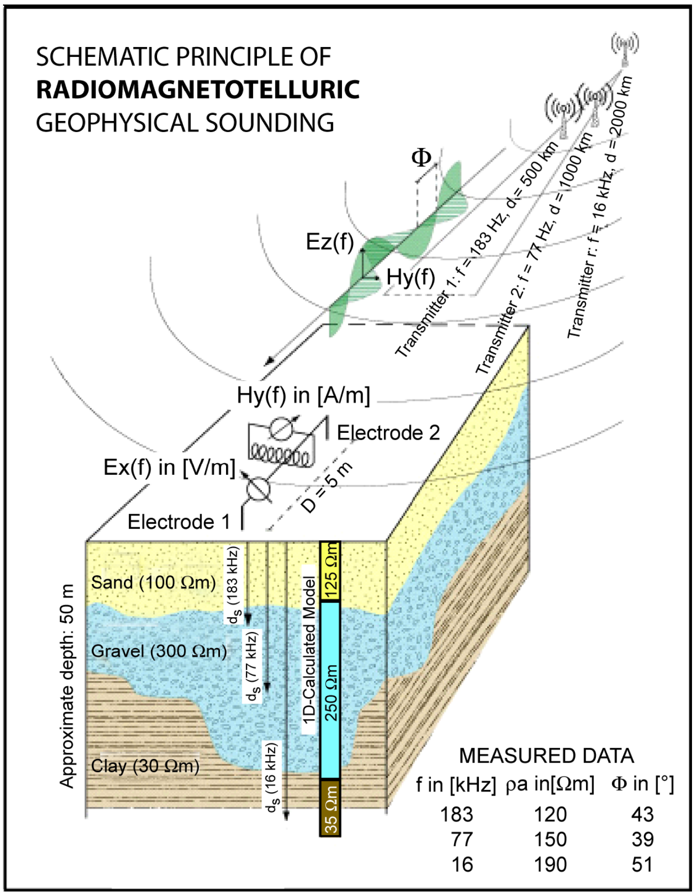

Fig. 1. Schematic principle of RMT sounding. $d_S(f)$ indicates the penetration depth of the transmitter-frequency (f)

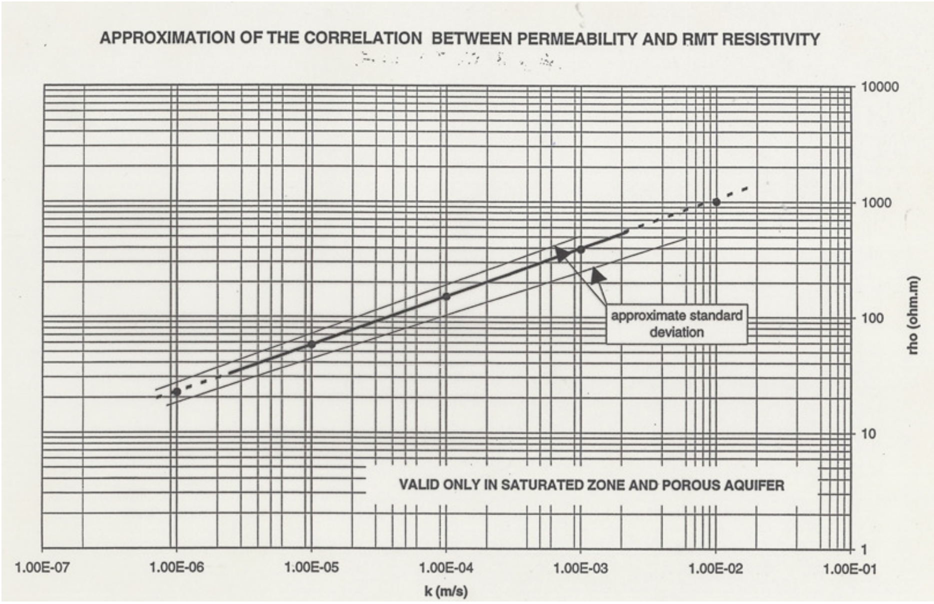

Fig. 2: Approximation of hydraulic conductivity obtained with RMT resistivities. Correlation is valid only with electrical conductivity of the water between 500-800 µS/cm at 25 °C.

Hungarian case studies

The investigated spring gallery of Pálihálápuszta (Transdanubian Central Range, Bakony Mts.) is situated in a binary karst basin. The karst part of the catchment is built up of Mid-Cretaceous Limestone, the non-karst part consists of Pleistocene Loess. The bedrock of both aquifers is a Mid-Cretaceous Clay-Marl.

Vulnerability of the spring gallery was assessed by using the European Approach in the frames of a methodological study related to COST-620. Due to the lack of sufficiently detailed geological and hydrogeological data, the reliability of this first assessment was rather poor the behaviour of the non-karst part of the reservoir and its contribution to the vulnerability was impossible to predict. The most obvious solution was to improve the reliability of the hydrogeological scenario with help of new data acquisition.

Several hundreds fast EM soundings (RMT) gave information about the areal extent of the catchment and the hydrostratigraphy (Ferenczi, 2003; Petró 2003). As a result of these investigations we had to modify the original "binary karst" model to a „porous and block-karst" model. Consequently a new conceptual model was developed which strongly influence the protection area of the catchment.

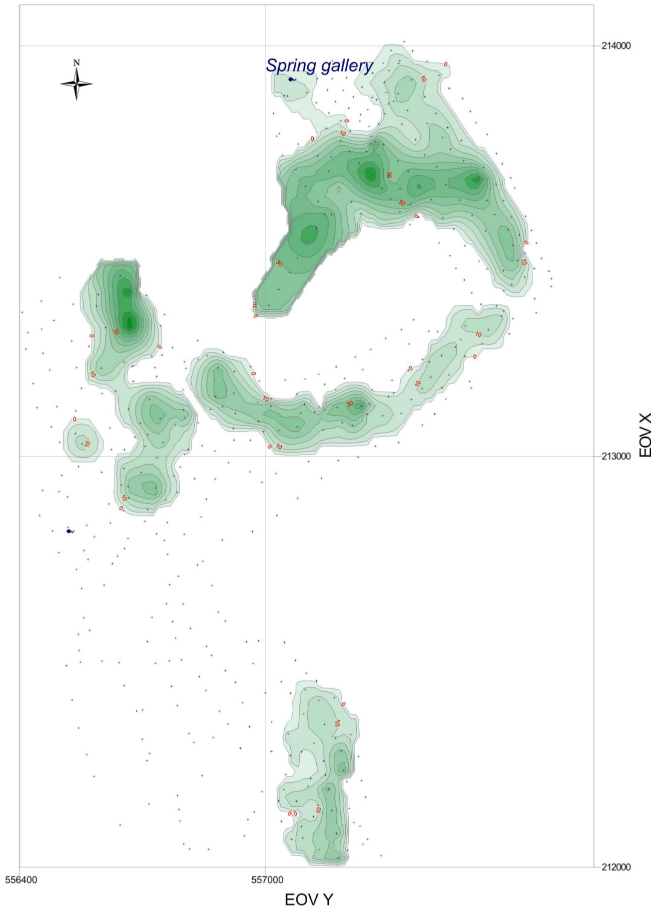

Fig. 3. Map of the hidden limestone reef bodies covered with several metres of aeolian Loess (Ferenczi, 2003)

The second test area is located at the Balaton Highland. In this area the RMT method allows to identify the most fractured zones in the field and estimate the direction and intensity of fracture development under several meters of aeolian overburden. The survey in the Paleozoic Sandstone show up a non fractured block (no phase difference between the multi-directional measurements) and a strong fractured block with a lineament (with large differences between the phase values) which allow us to locate the most permeable zone in the sandstone and plan a drillhole for water supply in the optimal place (Fig. 4).

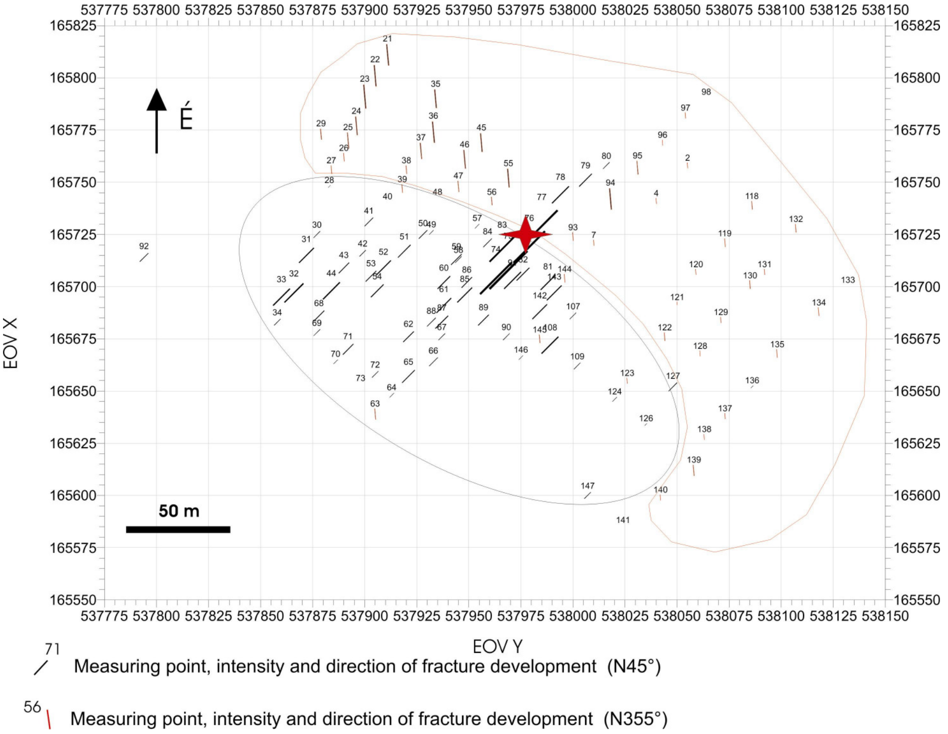

Fig. 4.: Proposed location for planned water well (red star) (after Csurgó, 2006)

Conclusion

The RMT seemed to be a fast and reliable tool to help hydrogeologist to obtain important information on a very local scale about heterogeneous distribution of permeability.

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The History of the Development of Keszthely as a Holiday Resort

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Abstract

The aim of our essay is to follow up the structural changes of the town of Keszthely from the 1800s to our time. The development of the town was first determined by craftsmen, merchants and the patronizing activities of the Festetics family. During the development of the town it had become a holiday resort by the 20th century as a result of the boom of tourism, and most of the residents lived on activities connected to tourism. In our time an industrial park in the outskirts of a town belongs to its structure, but in Keszthely it has not been established so far. As a result of the declining tendencies of tourism a solution must be found to compensate the loss of income of the residents from tourism so that we can make the town more attractive for industrial businesses.

1. Introduction

The aim of our essay is to keep a track on the structural changes of Keszthely from the 1800s to our time. As only few written memories exist of the time before 1800, we do not deal with that time in details, however we refer to that period. In the 1800s the patronizing activities of the Festetics family, while in the 19th century the boom of tourism, due to the construction of the railway, played an important role in the development of Keszthely. In the 19th century the town was divided into two parts, one of them was the area around the Franciscan church and the other one was the so-called Kiskeszthely, a burgher town.

In the 20th century the boom of tourism changed the citizens' orientation of livelihood and the emphasis from crafts shifted to tourism. The first hotels, the shore of Lake Balaton, and the rows of villas by the shore were built at that time. The significance of agricultural production, which had been very important because of the Festetics family, decreased. By the second half of the 20th century the main profile of the town was the reception of Hungarian and foreign guests. Nowadays the characteristic holiday resort feature has lost its significance, tourism has decreased, there are not industries in the town, therefore the leaders of the town must seek new perspectives for the residents.

2. The History of Keszthely until the 1800s

Earlier Keszthely was a much more famous settlement than it is today. In the Celtic times it was a prosperous town, during the Roman occupation it was the advanced post (castellum) of the Mogentia, the Roman fortress (castrum) of Fenék, in the period of the great migration it was a populous place, which is proved by the findings uncovered in the cemeteries of Keszthely, Páhok, Dobogó, Diás and Fenék.

Before the Hungarian conquest the Slavonian prince Privina had his residence in Mogentia near Keszthely, next to the lake of Zalavár, which has been dried out by now. During the time of the Árpáds and their ancestors, Keszthely was a privileged settlement a kind of junction as the famous Roman road to Acquincum, called the road of war because of the Hungarians, crossed the town, which owed its development to it. Keszthely was situated in the middle of this main road of world trade leading from the Adriatic Sea to Buda and the whole traffic to and from the sea went across Keszthely. During the Turkish occupation and mainly after the fall of Kanizsa, Keszthely became an important border fortress, during the Kuruc-Labanc times (Hungary's war of independence from Austria in the 18^{th} century), it was still one of the biggest settlements of Transdanubia (*Table 1*) (*Oppel* 1923).

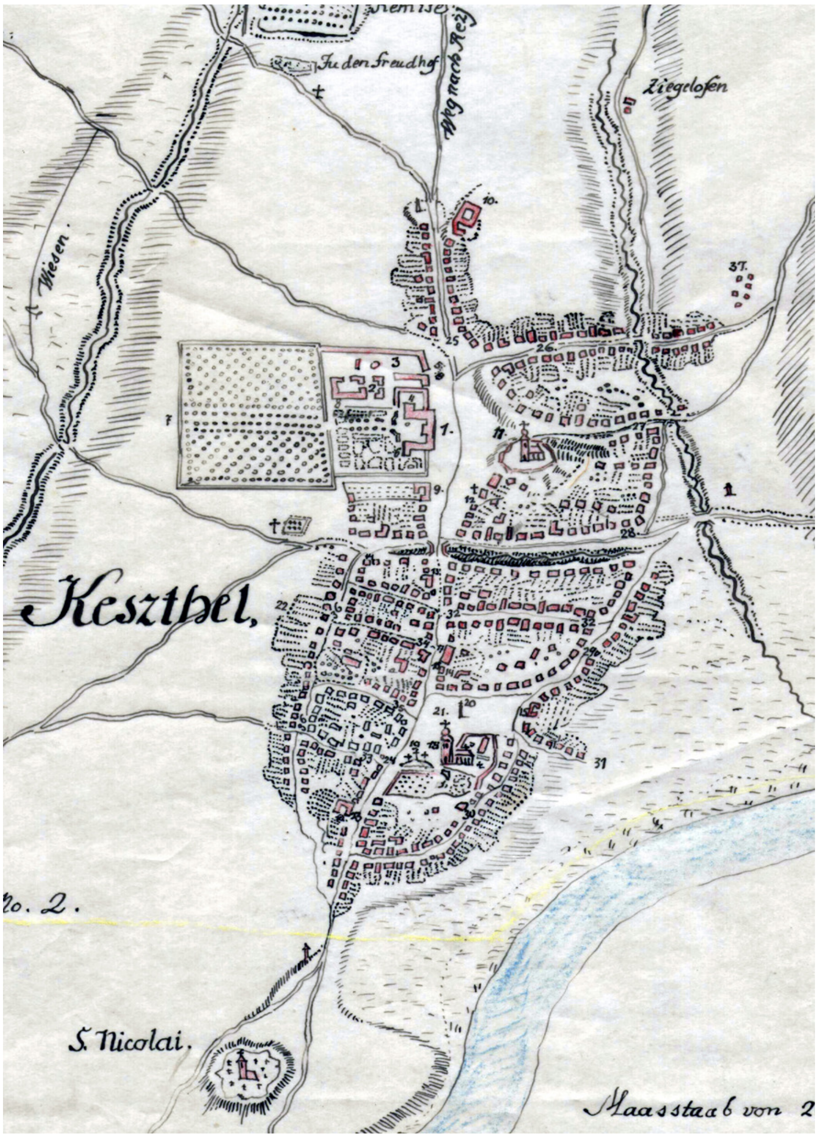

Table 1 Keszthely in 1770

In Keszthely urbanization started at the end of the 14th century and from that time Keszthely was the economic centre of the large estate at the north-west corner of Lake Balaton, which comprised several fortresses, towns and churches (*Koppány-Péczeli-Sági* 1962). In the

Middle Ages the church was the centre of the town and the settlement surrounded it. The settlement was a market town from the 13th century, the centre of which was the parish church functioning as a fortress at the same time. Its memory is kept in the Fortress garden next to the church in the Main square.

In Keszthely there were about 200-300 houses at that time. The town started to decline after the construction of the Southern Railway because at the beginning Keszthely was completely out of the way of railway transportation (*Oppel* 1923).

3. The development of Keszthely in the 19th century

Due to the school founding activities of the Festetics family, the intellectual development of the town was booming from the beginning of the 19th century. The secondary grammar school and Georgikon, the first agricultural high school of Europe, were founded.

Railway has always been outstandingly important in the development of a region. Keszthely was one of the stations of the Buda-Pragerhof railway, which was built in 1861 and went along the southern coast of Lake Balaton. Probably the boom of tourism in Keszthely was due to this fact and it led to the building of new hotels in the 1880s to serve the guests. These hotels, which still exist, were completed in the middle of the following decade.

Although the inauguration of the Keszthely-Balatongyörök branch line in September 1888 had local importance, it gave a lot of advantages for the inhabitants of the area.

Besides the construction of the first railway, 1861 is the starting date of the press. Among others it was the year when the Newspaper of

Horticulture and Industry was edited by the director of the School for Horticulturists and Viticulturists.

According to a guidebook published in 1889 Keszthely was a pretty, vivid town with a population of about 7000, where the inhabitants were mostly tradesmen and craftsmen. At that time it had only two inns but as the result of booming tourism private houses started to let their rooms. They had the opportunity because in 1890 – not including the burgher town - 589 houses existed in Keszthely. There were two four-storey, forty one-storey buildings, the rest of them had only ground floors (*Table 2*).

In the secondary grammar school, which were opened in 1892, Premonstrant friars taught young people. The building of the secondary grammar school was constructed according to the design of János Schandl, the teacher of the institution of economics.

Table 2 Kossuth Lajos street in the 19th century

Despite the fact that in 1900 Keszthely was not a town, but a village de jure, it could be regarded a central settlement, which had the functions of a town. Of the 6796 inhabitants 254 were tradesmen and 181 were civil servants. In 1908 the name of the Burgher town became Kiskeszthely (Littlekeszthely) officially. Between 1881 and 1900 the number of the inhabitants doubled.

7 August 1898 is a significant date in the life of the town: The Balaton Museum – Society directed by Sándor Lovassy was inaugurated then (*Tar* 2000).

4. The first half of the 20th century

"There are hardly any towns in the country, which, besides its poverty, and without the harder taxation of the residents, could make so much progress in material gain, the establishment of cultural and humanitarian institutions, than Keszthely during the administration of Reischl", *Boncz* (1896) wrote it his monograph about Keszthely.

In 1911 King Francis-Joseph promoted Earl Tasziló Festetics to the rank of a duke. In December the same year Imre Reischl was elected mayor unanimously.

Imre Reischl became the head of Keszthely in a difficult period. After some peaceful years, a period of war came, then the proletarian dictatorship, life returned to normal very slowly.

After some days of the “revolution of asters”, on 2 November 1918 the National Council was established in Keszthely and Mayor Imre Reischl was elected its chairman. In the meeting of the National Council on 3 November Chairman Imre Reischl resigned. He did not take part in the events of the year 1919 but after the collapse of the Hungarian Soviet Republic he returned as the mayor of the town (*Tar* 1992).

World War I took a heavy toll on every family including the family of the duke. Tasziló tried to help the town during the war as well, giving charity to people in need and orphans.

In the summer of 1921 the Helikon festival could be organized again, its main supporter was Tasziló Festetics. Large crowds of people came together including some of the well-known people of the country visited it for example Ferenc Móra, Zsolt Böthy, Ferenc Herczeg, József Vas, János Zichy, Albert Apponyi, and governor Miklós Horthy with his wife.

At the elections of 1930 Imre Reischl received the honourable chair of the mayor as he deserves the credit for laying the foundation stone of the Carmelite church, opening the beach (*Table 3*), and building the Balaton Museum and the Post Palace (*Tar* 1992).

Between the two world wars Keszthely was regarded as the town of pensioners. A lot of famous people were attracted by the town. The main problem was that Keszthely was not supplied with public utilities. The roads, the streets and the pavements were out-of-date together with street lighting.

Table 3 The shore of Lake Balaton in the 19th century

Keszthely was liberated on 30 March 1945. During the fights Keszthely did not suffer big destruction therefore it had the possibility to start a new life. Lake Balaton had a different role as well, as it became the lake of the whole country (*Table 4*).

The role of schools changed fundamentally, education became available for everyone. It is natural that the role of Keszthely as a school town and holiday resort increased in the new era (*Sági* 1975).

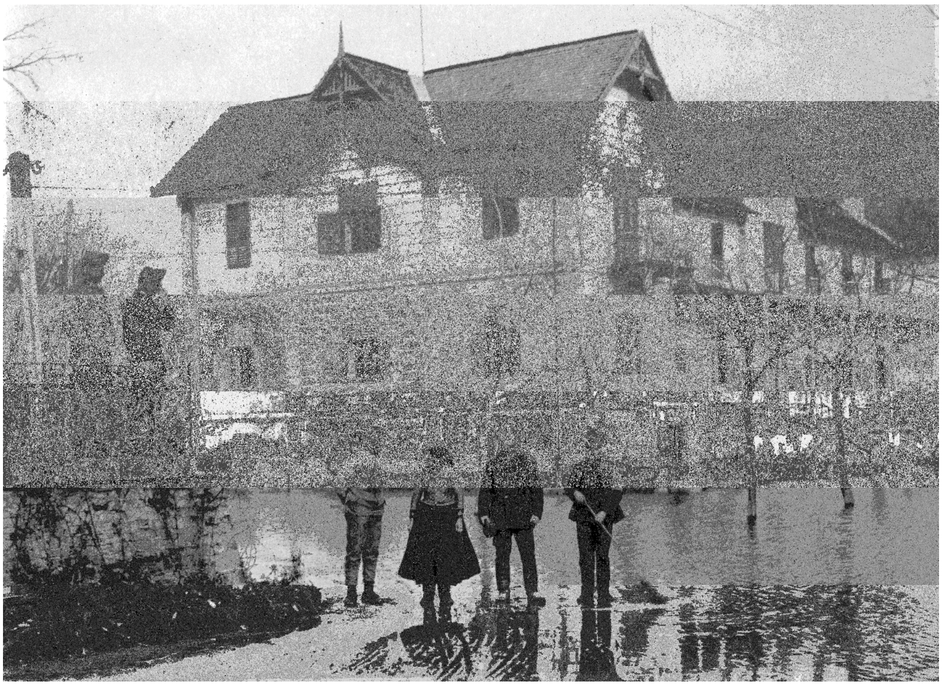

Table 4 The Balaton Hotel I the first part of the 20th century

5. From the 2nd half of the 20th century to our time

The Presidential Council of the People's Republic of Hungary promoted Keszthely to the rank of a town again on 1 February 1954 and in this way Keszthely had the opportunity to develop to the level of a town. In 1958 the work of the shore planning of Lake Balaton was started. In 1960 the modernization of the railway station was started and the work was finished in 1962. The Town Beach was opened in 1963. The new observatory of the Instituion of Meteorology was operated from June 1966 to 1999. In 1967 Keszthely was provided with a sewage system and the sewage plant was established. In 1971 the Power Supplier of South Transdanubia established a 120/20 kW plant with modern open air instruments. In 1972 the Fire Station was modernized, Keszthely started a way which was development leading to a modern town.

6. Conclusions

During the development of the town the initial agricultural character fell more and more into the background as an influence of the increasing tourism. In the areas next to Lake Balaton we could see the development of the buildings serving the guests (*Table 5*) while the residential areas with family houses fell into the periphery and the town centre became the centre of the service sector. Nevertheless in the 19^{th} century Keszthely kept the atmosphere of a market town. The character of the town is determined by the Helikon Castle Museum, which is situated in the centre. The main commercial areas have been transferred to the district between Keszthely and Gyenesdiás and to the northern part of the town. Nowadays an industrial park in the outskirts belongs to a characteristic town structure but in Keszthely it has not been established. As a result of the declining tendencies of tourism we should find a solution how to compensate the income loss of the inhabitants, who lived on it so far, and we should make the town more attractive for industrial businesses.

Table 5 The Island Bath on the Town Beach still keeps the silhouette of the old building

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RADIATION INTERCEPTION AND RAIN WATER USE EFFICIENCY IN COTTON BASED INTERCROPPING

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Abstract

Field experiment was conducted on crop diversification in cotton based vegetable intercropping at Agricultural Research Station, Kovilpatti Tamil Nadu, India during the monsoon season 2005-06 in randomized block design with three replications. In this investigation, productivity, radiation and rain water use efficiency of cotton intercropped with vegetables were tried in rainfed vertisol condition. The highest cotton equivalent yield was obtained from cotton + radish intercropping followed by cotton + onion. The rain water utilization efficiency for that combination was 1.98 and 1.93 kg ha^{-1} mm^{-1}. Substitution of cotton with short duration vegetables intercrops found more beneficial.

Key words: Radiation interception, intercropping, rain water use efficiency, rainfed cotton, vegetables.

Introduction

Cotton, popularly known as 'White Gold' is one of the most important and extensively grown cash crops of the world and plays an important role in agrarian and industrial economy. India accounts for approximately 21 % of the world cotton area but the average productivity of cotton is markedly low at about 293 kg lint cotton /ha as compared to 600 kg/ha of world average (Sen, 2003). In spite of low and unstable yield of cotton due to erratic monsoon, moisture stress during crop growth period, existence of biological constraints like weeds, diseases and pests, the traditional farmers of dry tract region grow cotton on such land because of high economic return when compared to other crops. Cotton crop is intercropped with either blackgram or greengram in southern dry tract of Tamil Nadu. Pothiraj and Srinivasan (1993) found cotton + redgram intercropping to be the most superior and concluded that multi-tier crop combination provided an efficient means of harvesting solar energy. Under this situation, crop diversification through intercropping with less duration and low water requiring crops may be one of the best options to the hands of the farmers for mitigating drought and increasing productivity (Kar et al, 2004). However, not much experiment has been reported in cotton with introduction of vegetables as intercropping. Cotton with vegetables in rainfed areas not only provides food security but also nutritional and economic security as well. Idea of crop diversification with vegetables in rainfed tract is to emphasize that these crops can provide an assured income under low rainfall situation. Hence, a detailed study was made of radiation interception and its utilization efficiency as influenced by substituted sole and intercropping form as an important supplementary component to improve the productivity of rainfed cotton area of Southern India. The light use efficiency is function of interplant and intra plant spacing and their competition for light and water. Intercropping intercepts photosynthetically active radiation more efficiently than does the sole crop under rainfed conditions (Singh et al, 2002)

Materials and methods

Field trial was conducted in rainfed area during September - February 2005 at Agricultural Research Station, Kovilpatti, Tamil Nadu, India. The climate of the experimental site was warm and dry. The soil of the experimental field was heavy textured and taxonomically belonged to category of vertisol under Kovilpatti series is a member of gneiss, Smectic Isohyperthermic family of typic chromusterts. The clay content of the soil varied from 13 - 24 %. The pH ranged between 7.8 - 8.3 which was moderately saline. The organic carbon content is 0.3 indicated low fertility status. In this investigation, the productivity, radiation and rain water use efficiency of cotton based intercropping consisting of Cotton + Radish, Cotton + Onion, Cotton + Cluster bean, Cotton + French bean, Cotton + Green chilli, Cotton + Tomato and Cotton + Bhendi were compared with that of sole cotton. The compodia Cotton KC 2 was used as test variety. The experimental design was randomized block design replicated thrice.

For measurements of biometric observations, one square meter sampling area was selected randomly from each experimental unit size of 5x 4 m. Dry weight of the plant materials was measured after drying the samples for 48 hours in a hot air oven at 80 °C. The amount of incoming, reflected and transmitted photosynthetic active radiation (PAR) was measured with Line Quantum Meter (Model LQ100-20 - Apogee Instruments Inc., USA.)

PAR inteception (%) was obtained as under:

$$\text{Intercepted PAR (\%)} = \frac{\text{PAR (I)} - \text{PAR(T)} - \text{PAR(R)}}{\text{PAR(I)}} \times 100$$

where PAR(I)-PAR incoming above the canopy, PAR(T)-PAR transmitted to the ground, PAR(R) -PAR reflected from the canopy

Heat use efficiency (HUE) was computed by using the formula as follows:

$$\text{Heat use efficiency g m}^{-2}\ {}^{\circ}\text{C days} = \frac{\text{Dry matter production (g m}^{-2}\text{)}}{\text{GDD (}^{\circ}\text{C days)}}$$

The growing degree days were computed by subtracting the base temperature from daily mean temperature as suggested by Ketring and Wheless(1989).

Several crops are involved in intercropping system, it is not logical to compare the total yield of different crops in one system with the other. The yields of different intercrops are converted into equivalent yield of main crop based on price of produce. The experimental data were analyzed statistically and the standard errors for mean difference (SEd) and critical difference (CD) were worked out at 5 % probability level (Gomez and Gomez, 1984) for comparison of different treatments.

Results

Intercepted photosynthetic active radiation and Heat unit efficiency:

The intercepted photosynthetically active radiation of sole cotton and cotton based intercropping was computed. The cotton based intercrops intercepted more PAR than sole crop. The radiation interception was found more (45%) when the crop was grown with radish that occurred at 30 days after sowing followed by onion. Heat use efficiency of different intercrops combination revealed that cotton intercropped with radish, onion, cluster bean and french bean registered the higher heat use efficiency (Table 1). Cotton intercropped with radish significantly showed higher HUE of 0.39 g m^{-2} ^{o}C days which was on par with cotton + onion (0.38) where as pure crop of cotton recorded lesser HUE followed by cotton +chilli (0.20)

From the study, it was revealed that radiation interception was higher in intercropping than that of sole crop. Cotton intercropped with radish followed by onion significantly registered higher interception of PAR than cotton intercropped with long duration vegetables. Similar results were reported in sorghum based intercropping system (Bandopadhey, 1987)

Cotton equivalent yield and Rainwater use efficiency

For better comparison, productivity of different cotton substituted crops was converted into cotton equivalent yield. Among the intercrops, cotton + radish recorded significantly the highest cotton equivalent yield followed by cotton + onion intercropping system.

Rain water use efficiency was computed in terms of cotton equivalent yield (kg ha^{-1}) produced per mm of rain water received during the growth period (Table 2). From the study, it was found that among different intercropping combinations, rain water use efficiency was the highest in cotton + radish intercropping followed by cotton + onion where as sole cotton achieved the lowest rain water use efficiency.

Discussion

Cotton equivalent yield in case of cotton intercropped with short duration vegetables (radish, onion, cluster bean) was higher than with long duration vegetables (green chilli, tomato, bhendi). It might be due to less competition between these two crops for light, nutrient and space owing to their different growth habits. In addition increased PAR absorption and heat use efficiency might have put forth increased growth parameters which in turn reflected on increased yield and higher rain water use efficiency when cotton was intercropped with radish and onion. Sole cotton registered lower heat use efficiency in the early stage might have due to slow growth and less canopy development. This is in agreement with the findings of Singh. *et al.,* (2002).

Conclusions

From the crop diversification studies in rainfed cotton, it can be concluded that cotton substitution with low water requiring vegetables like radish, onion, cluster bean and french bean were more efficient to utilize rain water and photosynthetically active radiation than long duration vegetables and pure crop of cotton which in turn reflected on increased yield.

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Table 1. Effect of cotton based intercropping on Heat Use Efficiency (HUE) and

Intercepted Photosynthetic Active Radiation

Treatments	HUE (g m^{-2} ^{o}C days)	Intercepted PAR (%)
Cotton sole	0.200	27.30
Cotton + Radish	0.393	45.00
Cotton + Onion	0.383	40.60
Cotton + Cluster bean	0.300	39.60
Cotton + French bean	0.306	38.00
Cotton + Green chilli	0.203	34.00
Cotton + Tomato	0.210	32.00
Cotton + Bhendi	0.236	37.00
SEd	0.022	7.50
$CD_{5\%}$	0.047	3.30

Table 2. Effect of cotton based intercropping on yield and rain water use efficiency

Treatments	Seed cotton yield (kg ha^{-1})	Yield of intercrops (kg ha^{-1})	Seed cotton equivalent yield (kg ha^{-1})	Rain water use efficiency (kg ha^{-1} mm^{-1})
Cotton sole	500	-	500	1.00
Cotton + Radish	375	5483	989	1.98
Cotton + Onion	410	3633	966	1.93
Cotton + Cluster bean	370	3166	750	1.50
Cotton + French Bean	360	1950	758	1.52
Cotton + Green Chilli	338	1433	509	1.02
Cotton + Tomato	310	2666	523	1.05
Cotton + Bhendi	368	2250	638	1.28
SEd	16	-	61	-
CD $_{5\%}$	34	-	128	-

INFILTRATION TO SURFACE RUNOFF RATIO ESTIMATIONS WITH SURFACE GEOPHYSICS IN THE TOPSOIL OF LOESS DEPOSITS (ZALA REGION, HUNGARY)

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Abstract

Three geophysical methods were applied to estimate infiltration to surface runoff ratio of topsoils in Loess environment. The test field (Tilaj, Zala county), divided in fallow land and plough-land, present similar magnetic susceptibilities and seismic velocities, but a significant difference is showed up by electrical resistivities, with a short Wenner array (a=0.5m). Due to the biological activities, the fallow land remain porous and permeable, thus favour good infiltrations. In this area the distribution of resistivities is heterogeneous and varies between 58 and 178 Ohmm. In the plough-land, also treated with chemicals, the biological activities diminish in the topsoil, producing clogging, and reduction of porosity and decrease of permeability. Surface runoff and erosion appears. In this part of the test field resistivities are low, 23 - 40 Ohmm and homogeneously distributed.

Keywords: topsoil, infiltration, surface runoff, surface geophysics

Összefoglalás

Három különböző geofizikai módszer paramétereivel próbáltuk megkülönböztetni azt a két egymással határos területet, egy régen parlagon heverő gyepet és egy művelés alatt lévő szántót, ahol a beszivárgás és a felszíni lefolyás aránya között nagy különbség figyelhető meg. A Löszön kialakult talajon (Tilaj, Zala megye) a mágneses szuszceptibilitás és refrakciós szeizmika egyforma értékeket mutatott ki a mintaterület mind két részén, de a geoelektromos szelvényezés, Wenner felállással (a=0.5 m), igen jelentős különbséget talált. A gyepet életben tartó biológiai folyamatok jó porozitást és permeabilitást biztositanak a talajnak és egyben jo beszivárgást is. Itt az ellenállások heterogén eloszlásúak, 58 - 178 Ohmm értékek között váltakozva. A szántóföld vegyszerekkel is kezelt talaja viszont biológiai aktivitás hiányában erősen tömörödik, porozitása és permeabilitása csökken. Itt a felszíni lefolyás és az erózió dominál. Erre a területre homogén eloszlású alacsony ellenállások a jellemzőek 23 - 40 Ohmm értékekkel.

Introduction

Vast regions of Hungary are covered with Quaternary eolian sediments, the Loess. These fine and well sorted dusts, with variable thickness, are mainly composed of siliceous grains more or less cemented with carbonate. Their terrestrial origin is marked by the presence of small fossil Gastropodes (Pupa muscorum, Succinea oblonga, Helix hispida) as indicated by Papp & Kertész (1965). In the region of Zala (Western Hungary) the thickness of these porous deposits vary generally between 2-10 m, overlaying Tertiary Pannonian clays, marls and sandstones (Hertai 2003). Loess terrains are fertile and precious compared to tertiary clays and marls, which seem to be poor quality for agriculture. Loess has low permeability: K about $10^{-6} – 10^{-7}$ m/s (Petro 2003) but constitutes often local aquifers feeding small springs with stable temperature and chemistry.

In the last fifty years not only climate is changing but also important transformations happened in the agricultural practice, introducing modification even in the water-cycle. These new methods compact the surface, destroying the superficial porosity of the soil, indispensable to favour fast infiltration under heavy rain or rapid snowmelt. On the other hand the compacted topsoil accelerates the development of an excessive surface runoff and thus the land-erosion. The disappearance of the fertile overburden by erosion would be a dramatic issue for agriculture. Several research projects tend to quantify the Loess degradation parameters. One of them, proposed by B. Csepinszky, measures in situ and on line, the erosion parameters in a field laboratory, assisted by a meteorological station and hydrometry. These exact methods are indispensables and constitute the best approach, but are expensive and time consuming. Our aim is to find out and propose a fast and simple geophysical test for qualitative estimation of infiltration to surface runoff ratio, in different setting of the land use. To experiment an adequate technique a small test site were delimited for the comparison of different geophysical methods, regarding the topsoil characteristics in both cultivated and non cultivated areas. This test site in the Zala department (Tilaj village) has the following UTM (1984) coordinates: 33 T 0656145 / 5186195; 06562000 /5185973; 0656143 / 5185958; 0656070 / 5186178.

The area is situated on a slightly sloping hill and can be divided in two parts by the coordinates: 0656098 / 5186047 and 0656170 / 5186075. The NW part is a yearly re-cultivated plough-land with intensive use of fertilisers and herbicides. The SE part is a long time not more cultivated prairie, a fallow land. On the cultivated area important surface runoff can be observed after each heavy rain or snowmelt event, with significant erosions phenomena, like erosions channels. On the fallow land, in the same period of weathering the surface runoff is rather negligible and the meteoric water infiltrates.

Material and Methods

Geophysical survey

The challenge for the surface geophysics is to characterize the infiltration to surface runoff ratio indirectly, with some simple but contrasting geophysical parameters, thus permitting to clearly discriminate the two parts of the test field having the same overburden. Several methods were tested to determine if any significant difference exists in the physical properties of these two domains, using magnetic susceptibility survey, refraction seismics and geoelectrical survey. Principles of these methods are extensively explained in several treatises (Kearey & Brooks 1993, Milsom 1989), therefore only a short summary is presented below.

The magnetic susceptibility is the ability of a rock to become temporarily magnetised while a magnetic field is applied to it. This temporary magnetisation is called induced magnetisation:

$$\textit{Induced magnetisation} = \textit{susceptibility} \times \textit{magnetic field} \qquad (1)$$

The value of the susceptibility of a rock depends on both the type of magnetic mineral (Magnetite, Hematite) and its concentration. Susceptibility itself has no units and the value is given by rationalised SI units. It can be measured directly in the field with a Kappameter. If magnetite is present in the rock, it is dominant for the susceptibility. The working hypothesis to undertake susceptibility measurements is that floods could introduce changes in the relative homogeneous distribution of the small but heavy magnetite particles and if sorting occurs during floods, the magnetite concentration and thus the susceptibilities could change in the test field. Over hundred measurements were done, in both areas, with a field kappameter (Mini-Kappa, Geofizika Brno). In the entire region the magnetic susceptibilities vary between 0.1 – 0.38 x 10^{-3} but doesn't exist any spatial anomaly. This means that in the test field of Tilaj the susceptibility is not a useful parameter to characterise and discriminate the surface runoff conditions between the two domains.

Seismic energy, a small earthquake, generated by a sledgehammer blow, can follow three main pathways under the ground from the source to receivers. The direct ray, the refracted ray and the reflected rays. They take different time to reach the receiver geophones and give the time-distance diagram. The velocity of the direct ray in the shallow depth is simply the distance along the surface divided by the arrival time measured by the seismograph. The velocities found from travel-time diagrams give a good indication of the type of rocks that form the layers, though rock types have a range of velocities due to consolidation. In general, velocity increases with compaction, so alluvium and loose sands have a very low velocity (300-500 m/s), cemented sediments, like Loess or sandstones, have a higher one (800-1500 m/s). The idea to apply refraction seismic in the test site is to detect some velocity differences in the topsoil between the plough-land and the fallow-land. Consolidation tends to increase the velocity in the same rock type thus reducing infiltration and favour surface runoff. Six refraction lay-out were done with a 6-chanel digital OYO seismograph, 1 m spaced geophones and 8 kg sledgehammer as seismic source. The time resolution was better than 0.1 millisecond. Using a rule of Thomb, that the geophone line should be ten times the depth, the penetration in the topsoil were limited to about 0.6 m. The measured velocities vary between 360 m/s and 395 m/s. These differences are not sufficient to discriminate, based on velocity contrasts, between the two areas of the test site.

Geoelectrical resistivity survey investigates variations of electrical resistance of rocks, by passing an electrical current to flow through the ground, using wire connected electrodes. The resistivity of rocks usually depends upon the amount of water present in their pores or fractures and on the amount of salts dissolved in it. The main uses of resistivity surveying are therefore for mapping the presence of rocks of differing porosities and permeabilities. Techniques have been designed to determine the vertical structures of a layered earth, as vertical electrical sounding, the VES, or lateral variations, as electrical profiling.

The resistivity characterise the material independent of its shape. It is measured in Ohmm by multiplying the resistance R (Ohm) with a geometrical factor (K).

$$Ohmm = R \ x \ K \qquad (R = Volt/Amper) \qquad (2)$$

Having four electrodes, two for current injection (mA) and two for measure potential differences (mV), we can lay out a resistivity array adapted for the type of investigation being made. The K factor depends on the particular array being used. To perform our electrical profiling the Wenner array were the best adapted for investigate the topsoil in a very shallow depth. The four electrodes were then equally spaced, 0.5 m from each other, along a straight line. With this separation referred to "a", the geometrical factor is:

$$K = 2 \; x \; \Pi \; x \; a = 3.14 \qquad (3)$$

So the resistivity is obtained by: Ohmm = 3.14 x milliV/milliA
The depth penetration of this very short array does not exceed 0.5-0.6 m. A precise DC resistivity meter with cooper electrodes served to achieve the numerous measurements in both sector of the test field.

Results and Discussion

Results of the geoelectrical survey are represented below (Fig. 1) and reveal a significant difference to discriminate the two domains. 36 measurements were done in the test field.
In the cultivated plough-land the topsoil resistivities vary only between 23 and 40 Ohmm, hardly contrasting with those measured in the fallow-land between 58 and 178 Ohmm. Probably, in the not cultivated prairie, as stated by Gobat & al. (1998) and Ensslin & al. (2000), the undisturbed biological activities, interactions of plants, microorganisms and animals, contribute to dislocate the soil. The topsoil is living. These heterogeneous, loose and porous sediments, characterized by relatively high electrical

resistivities are rather permeables and infiltrate heavy rains and fast snowmelts.

On the cultivated plough-land, treated by chemicals, the original and natural biological activities are destroyed and the topsoil become dead. The porosity is then clogged by fine silt and clay particles. This phenomenon is showed up by low electrical resistivities, thus indicating bad infiltration capacity and the development of intense surface runoff.

The resistivity distribution is homogeneous in the cultivated part, contrasting with a heterogeneous distribution in the fallow-land. We can clearly discriminate the two domains by appearance of a homogeneously low resistive area in opposition with a heterogeneous higher resistive part.

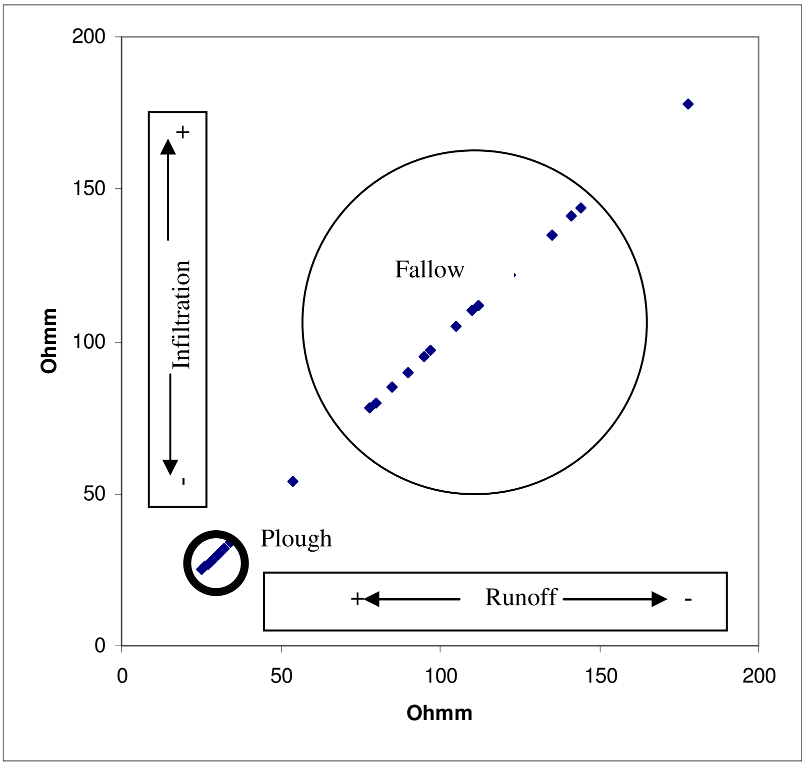

Fig. 1. Wenner (a=0.5 m) apparent resistivities distribution in plough-land

(small and thick with 16 values) and in fallow-land (large and thin circle with 20 values) at the Tilaj testfield.

Geoelectrical resistivity profiling with a short Wenner array, in Loess environment, seem to be an adequate tool for fast and extensive surface mapping to estimate topsoil permeabilities with erosion vulnerability issue. For hydrogeologists the presence of silt and clay, both having low geoelectrical resistivities, indicate low hydraulic permeabilities. Based on numerous measurements in the saturated zone of aquifers this "law" is already well documented and controlled by boreholes and pumping tests (Kelly & Mares 1993). In topsoil environments, in the unsaturated zone, the entire testfield of Tilaj must have more or less similar mineralogical constitution, but when the air-filling of pores is clogged by silt and clay particles, then the resistivities diminish hardly, because silt and clay has only 10-20 Ohmm electrical resistivity. In a very shallow depth, in the biological active zone, geoelectrical resistivities values could be than considered as "clogging" parameters, thus indicating erosion vulnerability. Vulnerability maps could be planed in hazardous areas with indication of the slope and Wenner resistivity.

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