SOIL TEMPERATURE STUDIES IN PÓTHARASZT

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Zusammenfassung: Der Verfasser bestimmt die verschiedenen Bodentype im Naturschutzgebiet der sandigen Waldsteppe von Csévharaszt und versucht die Bodenwärmeströmungen zu ermitteln. Der Aufsatz nimmt auch die verschiedenen Pflanzenassoziationen in Betracht und führt auch Bodentemperaturtagesgänge auf.

Summary: The author determines the different kinds of soil in the nature conservation area of the sandy wood steppe of Csévharaszt and tries to throw light on the conditions of heat flow in the soil. He also takes the different plant communities into consideration and presents diurnal variations of the soil temperature.

Simultaneously with microclimatological studies of the sands and woody steppe of Csévharaszt we also studied the temperature and heat flow conditions of the soils in this area. It should be noted that the heat flow studies relating to the soil were nct an end in themselves but served the general aim. We tried to find out what soil and soil temperature conditions ensure the development of the plant communities in Csévharaszt and in similar areas.

In this investigation we tried to demcnstrate the possible ways of heat flow in the soil characterizing the soil conditions. So the temperature conditions of the surface layers of the soil, the interaction of the air temperature conditions and a detailed assessment of other results of the investigation could not be in the centre of our attention.

The investigated area belongs to the alluvial fan of the land between the Danube and the Tisza. The deposit near the surface derives from pleistocene alluvial deposition of the Danube. The surface layers consist of sand, sandy silt and loess. Under the influence of the changing air currents after the area had become dry land, the alluvial deposit was morphologically altered.

The results of the investigation by PÉCSI (9) and MOLNÁR (8) explain the development of the quicksand formations in the area. The present deflationary formations of the surface have been developed in the period stretching from the end of the Pleistocene until now. The movement of the sand must have been the most intensive in the hazel — nut period of the Holocene. In some places the composition of the upper layers of the surface changed already within small distances. On the more elevated places — on sand deposits — textureless sand soil — quicksand —, humiferous sand and chernozyom — like sand were formed. In the old riverbeds and in the deflationary valleys mud and swamp meadow soils were formed.

The altitude of the area varies between 115—145 m above sea level.

The sand layer covering the soil surface generally contains calcium carbonate. In the neighborhood of the area, where enough humus and colloids have accumulated, uninterrupted agricultural production is going on. Owing to their composition the lower lying parts are much more fertile than the higher parts of the table-land. The quicksand has been tied by groves; especially in the lower parts.

The observations serving as a basis for this study were carried out in the western sector of the woods of Csévharaszt which is a protected area; it lies south-west of the village of Monor, and the distance by road is 6 km. The investigated area belongs to the village of Csévharaszt and figures under the name of Pusztacsév on the political map. The wood is wedged in between the villages of Inárcs and Csévharaszt in a north-west to south-east direction. The unbroken woodland of 30 km² surface is composed of the woods of Pótharaszt, Gombos. Buckás, Puszta Pótharaszt and Kelemen.

Investigation in the above-named regions was confined to the 6 km² area of the wood of Buckás. The denomination of the areas of observation was made on the basis of the morphological conditions and the plant communities (10). They were: the space between sandhills, the sandhill top, the steppe meadow, the *Quercus robur* stand, the juniper brushwood with poplars, the sedge meadow, the oakwood with lilies of the valley and the grove with poplars.

The only difference in the instrumental equipment used in the different places was only the number of the air and soil thermometers and their maximal level — depending on the vegetation. Generally the following instruments were employed: air thermometers (resistance thermometers) between 10 and 500 cm height, soil thermometers to 30 cm depth from the surface (partly mercury, partly resistance thermometers), psychrometers in 10 and 150 cm height (Assman's type), anemometers and wind vanes in 1 m height, rain-gauges, sunshine meters (Campbell-Stokes's type), radiation intensity meter (Robitzsch's type), and in three places, i. e. in the space between the sandhills; on the steppe meadow and on the sedge meadow, instrument shelters with the usual equipment were set up. With this instrumental equipment we secured complex measurements on the basis of which we could establish vertically and horizontally formed microclimatic spaces (5).

In this study, however, as we have already mentioned in the introduction, besides investigation of the soil, problems of heat flow connected with the soil conditions were in the centre of our attention. Accordingly reference to the complex results is made only occasionally.

Measurements were carried out from 11 to 21 July 1960, from 25 to 28 April, from 31 October to 4 November 1962, and from 28 October to 2 November 1963.

The majority of the data were provided by the summer measurements; the spring and fall measurements furnished control material in the first place. The measurements were carried out in spring before the development of the foliage, in summer in the period of vegetative and generative development when the temperature culminates and in autumn before the falling of leaves. We think it is not unecessary to mention that the theme with all its complexity is a part subject of the PT (Productivity of Terrest Communities) section of the national plan of IBP (International Biological Program).

In summer soil samples were produced by boring, in fall by digging. In both cases the general examination of the samples was done by an expert of the Agricultural Experimental Institute in Southern Hungary.

It is old knowledge that even within smaller units of the soil surface the characteristics such as situation, exposition, humidity, water permeability, vegetative cover, smoothness or roughness of the surface are often different. These are factors always influencing the heat condition of the soil surface, the water exchange and not in the least the microclimate.

According to our aim we deal in the first part of our study with the soil conditions of the places of observation and in the second part with the possibilities of the heat flow in the soil.

I.

The results of the soil examinations were compared with the findings of KÁROLY SIK which, although not in detail, apply also to the woody areas investigated by us (5).

1. On the basis of sedmentation the soil of the **sandhill top** can be classed as rough sand and fine sand. On the basis of the results of the examination of soil samples shown in Table 1 the following statements can be made. The soil of the sandhill top contains little clay and silt, and calcium carbonate only in traces. The low capillary water-lifting capacity of the layers near the surface of the soil suggests that the soil contains much undecomposed organic matter. The subsoil water is low. The hygroscopic values (hy, Table 1) are small. The plants develop too slowly. The chemical effect of the soil is slightly alkaline in the whole depth of the sample (pH, Table 1). The surface of the terrain is hilly. The trend of the sandhills is north-east and south-west. The basic material of the soil sample is sand. The upper layer is sharp to the touch, especially in the dry state, and without texture. The soil conducts water well, yet little water remains in the root zone because there is no impermeable layer near the surface. The thickness of the humus layer is very small, 15 cm on the average, and this layer is very loose.
The water-conductivity of the soil is good. The intergranular spaces are great. The maximal depth of the penetration of the roots is 25—30 cm. The development of the plant communities depends to a great extent on the humidity of the soil. Downward of 20 cm in the soil there is not enough organic matter and so it cannot store nutrients in the form of solutions. The level of the subsoil water on the sandhill top cannot be ascertained because around 2 m depth it is impossible even to make deductions about the wetter layers.

2. On the basis of the sedimentation values the soil of the **space between the sandhills** may be classed with the kinds of sand. On the basis of compactness we came to the same conclusion. Here the clay and pure mud content is somewhat larger than on the sandhill top. The capillary water-lifting capacity grows with the depth of the layers. The great waterlifting capacity of the upper layers in this case suggests (after 5 hr, Table 2), that the larger part of the organic matter that has got into the soil is already decomposing. The values of hygroscopy here are on average greater than on the sandhill top. On the basis of its $CaCO_3$ content the soil may be said to be calcarious.

In the space between the hills the decomposition of organic matter

Table 1.

Data of the soil sample from the sandhill top

Depth of sample cm	Sedimentable part %	Index of compactness Ke	hy %	Capillary waterlifting capacity after 5 hr	pH in H_2O	Calcium carbonate content %	Salt %
10	2	30	0,25	160	7,5	tr	0,02
20	2	30	0,25	160	7,5	tr	0,02
30	3	30	0,20	345	7,5	tr	0,02
40	3	19	0,20	345	7,6	tr	0,02
50	3	25	0,18	345	7,6	tr	0,02
60	4	20	0,18	345	7,7	tr	0,02
70	4	26	0,16	345	7,7	tr	0,02
80	14	21	0,15	320	7,6	tr	0,02
90—200	14	20	0,15	320	7,5	tr	0,02

Depth of soil sample cm	The investigated area	Surface of layers	Physical soil kind	Morphological structure	Thickness of humus layer cm	Depth of roots cm
0— 15	hilly	light	fine	sand	15	25—30
15— 83		browh	sand	sand		
83—111			sand	colorless		
111—204			sand	sand		

Table 2.

Soil sample data from the space between the hills

Depth of soil sample cm	Sedimentable part %	Index of compactness Ke	hy %	Capill. wat.—l. capac. after 5 hr	pH in H_2O	Calcium carbonate content %	Salt %
10	5	31	0,32	300	7,4	6,4	0,02
20	5	34	0,32	300	7,5	5,6	0,02
30	5	35	0,35	300	7,7	8,5	0,02
40	7	21	0,30	300	7,7	8,1	0,02
50	15	21	0,30	300	7,8	9,4	0,02
60	15	21	0,31	300	7,7	8,5	0,02
70	16	20	0,25	300	7,7	11,5	0,02
80—200	14—15	21—30	0,19—0,31	300—350	7,6—7,7	7,7—10,4	0,02

takes place under anaerobic conditions. The calcium content always accelerates the decompcsition of organic matter. The surface of the investigated area is slightly undulating. Yellcw is the dominant color in the surface layers:

its basic material is sand in coarse and in fine gleyey variation. Its structure is slightly crumbly, granular. It is known that gleyey areas are not favorable for plants even on sand because reductive processes take place in them. If the gleyey layer is under the root zone, it may retain water.

On sandy soils the more compact part ensures better life conditions for the plants.

In our soil sample the humus layer is already somewhat thicker than on the sandhill top. The rather coarse sand layer is dry here but downward from the gleyey layer it is slightly humid. There is more humidity among the roots than on the sandhill top. The depth of the roots changes in each square meter depending on the depth of the humus layer. It is only the roots of the juniper brush that penetrate through the gleyey layer. As a result of good water-lifting capacity, the influence of the subsoil water can already be noticed in the lower part of the 2 m deep sample.

3. In the soil of the **steppe meadow, the Quercus robur stand** and **the juniper brushwood with poplars** coarse sand is found in the top layer, and fine and gleyey forms are found deeper down. The capillary water-lifting capacity of this soil is great. The larger part of the organic substances getting into the soil is already decomposing. Its chemical effect is neutral. It is a soil poor in calcium (Table 3). The surface of the area is slightly undulating; the basic material of the soil is sand. The dominant color of the layers examined is brown. The upper part is coarser, but under it fine and then gleyey layers are to be found.

The structure of the soil is slightly crumbly near the surface, under this it is sandy, in places compactly sandy in stripes. The average thickness of the humus is 60 cm. In the area of the oakwood and the juniper brushwood with poplars depending on the thickness of the humus layer, the plants are much more vigorous than in the sector of the steppe-meadow and the sandhill top. The soil in all the three areas conducts water well, and there remains

Table 3.

Soil sample data of the Quercus robur stand and the juniper brush with poplars

Depth of soil sample cm	Sedimentable part %	Index of compactness Ke	hy %	Capill. wat.—l. capac. after 5 hr	pH in H_2O	Calcium carbonate content %	Salt %
10	8	33	0,4	380	7,2	tr	0,02
20	9	27	0,4	380	7,3	tr	0,02
30	9	29	0,4	360	7,3	tr	0,02
40	10	25	0,5	364	7,4	tr	0,02
50	12	29	0,6	325	7,5	tr	0,02
60	12	26	0,6	334	7,5	tr	0,02
70	12	24	0,7	340	7,5	tr	0,02
80	14	30	0,6	350	7,5	tr.	0,02
90	14	25	0,6	346	7,5	tr	0,02
100	14	25	0,6	328	7,4	tr	0,02
120—200	18	25	0,6	326	7,5	tr	0,02

more water in the root zone than on the sandhill top and between the sandhills. The rich growth of roots penetrates through various sandy layers. The decomposition of the organic matter accumulated in the *Quercus robur* stand and in the juniper brushwood with poplars is slow. Calcium carbonate, as indicated in Table 3, can be found only in traces. The lower part of the soil sample is humid, airless; its capillary waterlifting capacity is greater than in the region of the sandhill top.

4. On the basis of sedimentation and compactness the soil of the **sedge meadow** can be classed as a kind of mud. On the other hand, the hygroscopy values and the five-hour capillary water-lifting suggest clayey mud. The circumstances of its development are the same as those of meadow clay, but its composition is different. The basic rock of the basin bottom with low subsoil water is fine sand and silt. The layers are compact, their calcium carbonate content is very high. On the basis of its pH and its $CaCO_3$ content the soil may be considered highly calcarious. The water supply of the soil is good. Calcium precipitation is common. The subsoil water is relatively high. The waterlifting capacity of the soil is, in comparison with that of the space between the sandhills and its neighborhood, rather low (Table 4).

The organic substances in the soil decompose rapidly. The meadow area formed in the filled- up bed is gradually drying out and in the course of time the earlier rich vegetation has become stunted. The colors of the soil layers from the surface downward are brown, black, yellow and greyish white. Under the uppermost layer of fine sand there are kotu, peat and mud layers. There is, however, too little peat in the soil, it is not fit for exploitation. In the 80 cm thick humus layer there is relatively much organic matter. The roots have penetrated to a depth of 50—80 cm on the average. The depth of the subsoil water is very variable, in places it is 1,5, elsewhere 2,5—3 m.

The sedge-meadow is the part with the richest vegetation in the area the natural result of which is that its fauna is also rich. There are more roes, rabbits and pheasants living in this part than in the other investigated areas altogether.

5. The soil of the **reeds mixed with nettles** between the sedge-meadow and

Table 4.

Data of the soil samples from the sedge-meadow

Depth of sample cm	Sedimen table part %	Index of compactness Ke	by %	Capillary water lifting capacity after 5 hr	pH in H_2O	Calcium carbonate content %	Alkalinity as soda %	Salt %
10—20	28	36	2,6	185	7,5	39,3	tr	0,02
20—60	35	40	3,4	172	7,5	50,8	tr	0,02
70	36	41	3,6	171	7,7	64,0	tr	0,02
80—90	39	42	3,8	142	7,8	68,4	tr	0,02
100	32	39	3,4	135	7,8	62,0	tr	0,02
110—200	31	40	3,9	125	7,9	68,5	tr	0,02

Table 5.

Data of the soil samples from the reedbed with nettles

Depth of sample cm	Sedimentable part %	Index of compactness Ke	hy %	Capillary water lifting capacity after 5 hr	pH in H_2O	Calcium carbonate content %	Alkalinity as soda %	Salt %
10	24	37	1,7	80	7,5	35,9	tr	0,06
20	24	37	1,7	80	7,5	39,9	tr	0,06
30—40	35	39	2,3	70	7,5	43,6	tr	0,06
40—60	60	42	2,8	80	7,6	62,0	tr	0,06
70	68	43	5,2	45	7,8	64,5	tr	0,02
70—90	68	42	5,0	82	7,8	63,2	tr	0,04
90—140	30	32	1,0	240	7,8	ny	—	0,06
140—200	28	32	0,8	390	7,7	ny	—	0,06

the oakwood with lilies of the valley is sandy mud to a depth of 40 cm, silt to 90 cm depth and from it downward sandy mud again. The values of compactness and of sedimentation are in agreement (Table 5). The hygroscopy values also prove the reality of the values mentioned.

According to its chemical effect the uppermost layer is slightly alkaline with a high calcium carbonate content. The decomposition of the organic substances in the soil is ensured. There is much organic matter accumulated in this place once covered with water which used to be the bottom of a swamp. After draining humus formation began. The calcium carbonate content is characteristic of the uppermost 1 m deep layer only (Table 5).
The thin layer of muddy clay hinders deeper penetration of the roots.

The reedbed with nettles and the oakwood with lilies of the valley have also kotu swamp soil formed on calcaricus sand. The kotu layer is mixed with the swamp soil. The level of the subsoil water is high. Its capillary water lifting capacity increases from the surface upward except in the clayey layer. The color of the soil layers from the top downward is very variable: brown, black, yellow and greyish white. The layers differ from each other sharply in color. The basic material of the layers is sand, for the most part compacted; in the black stripe there is another thin humus layer of greenish grey color. The ferrous compounds in it are reduced. In the root zone the iron veins can well be seen with the naked eye.

6. The soil of the **oakwood with lilies** of the valley and of the **poplar grove** is *mud in the top layers, with muddy sand under it in more firmly bound form* in places. The water conductivity of the soil gradually decreases downward; on the other hand, its water-storing capacity is good. Its swelling and shrinking ablity is great. The top layer is liable to dry out quickly in summer if there is little precipitation. On the basis of the pH values (Table 6) the soil can be regarded as a slightly alkaline variety.

It is a flat area higher than the reedbed with nettles and the sedge-meadow. The color of the soil downward from above is brown, black, yellow and greyish

Table 6.

Data of the soil samples from the oakwood with lilies of the valley and from the poplar grove

Depth of sample cm	Sedimentable part %	Index of compactness Ke	hy %	Capillary water lifting capacity after 6 hr	pH in H_2O	Calcium carbonate content %	Salt %
10— 60	26—27	27—35	1,57—2,77	140	6,9—7,4	—	0,02
60—100	45—64	37	3,45—3,77	135	7,1—7,8	0—4,7	0,02
100—200	64—74	34—56	3,45—5,39	128	7,6—7,8	4,7—30,8	0,02

white. These colors are sharply separated from each other. The uppermost layer near the surface is mud, and under it there is muddy, clayey sand. Of all the investigated areas it is here that the humus layer is the thickest — 100 cm on the average. Corresponding to the thickness of the humus layer, the roots of the vegetation are very well developed. The layers above the muddy clay are very wet. As in the reedbed with nettles, the subsoil water is very high. The organic substances in the humus layer transform themselves only with difficulty. Their transformation is hindered by the anaerobic conditions.

II.

After evaluation of the data of the soil samples we come to a quantitative description of the vertical heat flow in the soil.

When the approximately periodically changing diurnal temperatures get under the surface of the soil, it is possible to determine how fast the thermal wave spreads toward the lower layers and what temperature can be expected in a place at a given time.

From the general formula of heat conductivity (12) a correlation can be deducted concerning the distribution of temperature T in the case of one-dimensional spreading. In case of constant heat flow in one direction the temperature gradient is $\frac{\Delta T}{\Delta X}$ = constant and starting from a temperature of I_0 in an x = 0 place toward lower temperatures, for instance going downward from the surface of the soil, yet near the surface, the temperature T decreases proportionally with the distance. So in a place x near the surface

$$T = T_0 - \frac{\Delta T}{\Delta X} x \tag{1}$$

If we communicate heat periodically in the place x = 0 on the surface of the soil, then upon the temperature distribution under (1) a periodically changing temperature distribution is superposed. At the place x = 0, assuming a sinoid periodicity, the temperature is:

$$T^{*}_{0} = T_0 + T_m \sin \omega t,$$

where T_m is the maximal change of temperature, $\omega = 2\Pi f$(f = the frequency of periodic warming).

The general formula of heat conduction in the case of one-dimensional propagation is:

$$\frac{d^2 T}{dx^2} = \frac{cd}{k} \cdot \frac{dT}{dt} \tag{2}$$

where *d* is the density of the medium, *c* its specific heat, and *k* the coefficient of heat condcution. The solution of a linear and homogeneous differential equation of this kind under the known limit conditions is:

$$T = T_0 - \frac{\Delta T}{\Delta X} X + T_m e^{ax} \sin(\omega t + bx) \tag{3}$$

where *a* and *b* are constants, T is the temperature at a time t at a distance x from the surface, and *e* is the basis of the natural logarithm. We obtain the values of the constants by forming the differential quotients necessary for (2) from (3) and substituting them in (2). Thus with the constants the final form of equation (3) can be written (12). The distance of two consecutive places of maximum is the length of the temperature wave which is expressed by the value λ. Using this

$$\frac{k}{cd} = \frac{f \cdot \lambda}{4 \Pi}$$

This expression allows us to know $\frac{k}{cd} = D$ (the so called heat diffusion constant or temperature conductivity (if we know *f* and λ, and if *c* and *d* are also known we can determine *k*. Applying the solution method above — using the values *c* and *d* got from laboratory measurements — we found that the heat conductivity (k), the specific heat (c), the density (d), and the temperature conductivity of the soils examined by us are varied. These data are shown in Table 7. The values of specific heat and density are mean values of the samples from 10, 50, and 100 cm depth.

Of the properties of the soil surface the material quality plays an important role in the transmission of energy. The energy of absorbed and scattered radiation depends among others on the absorbing or reflecting capacity (albedo) of the surface. An important quality is the specific heat; its differences cause even in case of equal energy absorption different degrees of warming both in the uppermost and in the deeper layers of the soil (3—4).

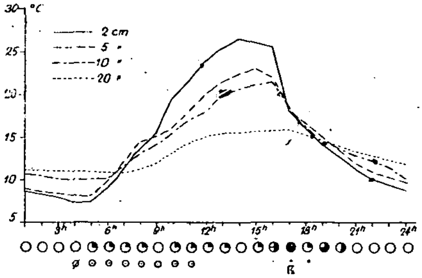
In Table 7 we can see the differences between the specific heat and density values of the sandy and clayey soils examined. *Considering that of the substances forming the soil surface the dry earth and the water surface show the greatest difference in specific heat (3) our findings are consequent since the specific heat of the low-lying, wet areas (e. g. the sedge-meadow and its neighborhood) is greater than that of the higher dry soils (e. g. the sandhill top and its neighbor-*

Table 7.
Heat conductivity, specific heat, density and temperature conductivity of the soils

Area	k cal cm^{-1} deg^{-1} min^{-1}	c cal/deg g	d g/cm^3	D cm^2 sec^{-1}
Sandhill top (sand)	0,18	0,20	2,05	$7,3 \cdot 10^{-3}$
Space between hills (sand)	0,19	0,21	2,24	$6,7 \cdot 10^{-3}$
Steppe-meadow (sand)	0,18	0,20	2,05	$7,3 \cdot 10^{-3}$
Quercus robur wood (sand)	0,17	0,21	2,14	$6,2 \cdot 10^{-3}$
Juniper brushwood with poplars (sand)	0,17	0,21	2,12	$6,3 \cdot 10^{-3}$
Sedge-meadow (sandy clay)	0,20	0,28	2,38	$5,0 \cdot 10^{-3}$
Reedbed with nettles (sandy clay)	0,21	0,28	2,48	$5,0 \cdot 10^{-3}$
Oakwood with lilies of the valley (clay)	0,15	0,30	2,25	$4,0 \cdot 10^{-3}$
Poplar grove (clay)	0,15	0,34	2,20	$3,3 \cdot 10^{-3}$

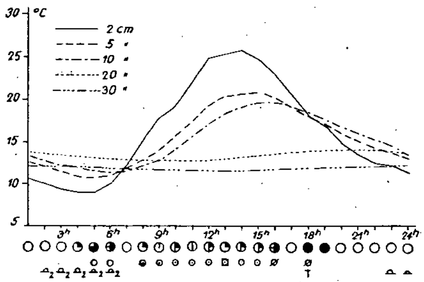
hood). Under identical radiation conditions, or we may say, in case of similar energy absorption the warming of soils with smaller specific heat is greater than that of soils with greater specific heat, as for instance in the neighborhood of the sedge-meadow. When similar energy is given off, cooling is less intensive in the region of the sandhill top than in soils with greater specific heat (Fig. 1.) The fact, that in clayey soils the heat conductivity (k) and what is essentially the same, the heat diffusion constant is smaller than in sandy soils, explains the phenomenon seen in Figs, 1 and 2 that the temperature wave cannot be noticed in 20 cm depth under the soil surface of the sedge-meadow while it is very pronounced on the steppe-meadow.

The densities of the sandy soil of the sandhill top, the space between the sandhills, the steppe-meadow, the juniper brushwood with poplars and the Quercus robur stand differ, even though slightly, from the densities of the soil of the sedge-meadow and the reedbed with nettles in spite of the fact that the wet areas investigated by us contain an abundance of organic matter. The densities of the soil, the oakwood with lilies of the valley and the poplar grove in which there is also much organic matter differed minimally from the density of the higher-lying dry sand. This difference was enough to influence the soil and air temperatures (1, 4).



The diurnal variation of temperature on the steppe-meadow

The diurnal variation of the soil temperature on the sedge-meadow



In the same length of time the humid soil of the reedbed with nettles, the sedge-meadow, the oakwood with lilies of the valley, and the poplar grove warmed up from the same amount of energy to a smaller degree than the soil of the dry sandhill top and of its neighborhood (Fig. 2). The difference in warming is increased by evaporation because the wet soil uses part of the energy for evaporation and less is used for warming. It follows from this that the surface of wet soils, like that of the sedge-meadow and the reedbed with nettles, is colder than the surface of dry sand soils. This effect manifests itself of course also in the temperature of the microclimatic air layers near the soil (1, 5).

In the fate of the energy reaching the surface other important factors besides the differences of specific heat and density of the soil are the heat conductivity and the temperature conductivity. These two factors have a decisive influence on the velocity of heat transfer in the soil as well as on the substitution of the heat energy radiated from the surface.

The differences in the heat conductivity and temperature conductivity of the sandy and clayey soils are connected not only with the specific heat but also with the air content of the soils. When taking soil samples it was established that the clayey soil or sandy day soil of the sedge-meadow and its neighborhood, owing to the presence of much undecomposed organic matter, contains much more air than the sand which is prevalent in the region of the sandhill top although sand is also a loose material containing much air. On the basis of the organic matter contained in the soils we could already infer that differences in the heat conductivity and the temperature conductivity of the soils were to be expected.

Using suitable calculations (12) it is possible to determine the velocity of the propagation of the daily temperature wave

$$v = \sqrt{4\pi \frac{k}{cd} f},$$

and the time needed for the maximum to reach 1 m depth:

$$t = \frac{x}{v} = x \sqrt{\frac{1}{4\pi D f}}$$

It should be noted that the results obtained by calculations of this kind are in many respects strongly approximative chiefly because the structure of the soil is not homogeneous and the heat propagates not only vertically.

Table 8. The velocity of the propagation of the soil temperature wave in cm/sec. its time of propagation in hr to 100 cm depth

	v cm/sec	t hr
Sandhill top	$10,2 \cdot 10^{-4}$	27,2
Space between hills	$9,8 \cdot 10^{-4}$	28,9
Steppe-meadow	$10,2 \cdot 10^{-4}$	27,2
Quercus robur stand	$9,5 \cdot 10^{-4}$	29,2
Juniper brushwood with	$9,5 \cdot 10^{-4}$	29,2
Sedge-meadow	$8,5 \cdot 10^{-4}$	32,5
Reedbed with nettles	$8,5 \cdot 10^{-4}$	32,5
Oakwood with lilies of the valley	$7,6 \cdot 10^{-4}$	36,5
Poplar wood	$6,9 \cdot 10^{-4}$	40,1

The results of our investigations obtained on the basis of summer and fall soil samples are as follows:

The differences in the approximate velocity and time of propagation can be demonstrated also qualitatively. These differences influence, of course, the soil temperature (5).

The wet soils, rich in humus and containing much air like the soils of the poplar grove, the oakwood with lilies of the valley, the reedbed with nettles, and the sedge-meadow warmed more slowly even in case of the same energy absorption depending on the values k, c, d and D than the drier soils poorer in humus of the sandhill top and of the steppe-meadow. It must be noted here that the surface of the soils was covered by various plant communities (10). It is only in uncovered soil that the soil temperature can manifest itself undisturbed in the form described by us. The covering of the soils investigated and generally the covering of the soil, results in essentially different soil temperature conditions.

In case of vegetable covering, a part of the energy-transmitting role of the soil is taken over by the vegetation above the surface (3). In the case of very dense vegetation, as in the oakwood with lilies of the valley and in the poplar grove, the surface of the soil receives a minimal amount of the prevailing irradiation in consequence of which it warms up and cools down less. The active surface on the soil, depending on the vegetation, almost ceases to exist in some cases and is transposed to the surfaces of the various kinds of vegetation (5).

In this study we have attempted to show the heat flow in the soil besides characterizing the soil conditions. We have discussed only briefly the warming of the soil, the role of the vegetation in the development of the different active surfaces, because these themes require a special study due to their importance.

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