THE INFLUENCE OF THE WIND CONDITIONS OF THE HUNGARIAN ALFÖLD ON THE GEOGRAPHICAL DISTRIBUTION OF MILLS

by Ilona Bárány, Etelka Vörös and R. Wagner

Summary: The geographical distribution of the mills which were still working at the turn of the century and can be found on official Hungarian maps can be related with the wind conditions. With their help we can attempt to research the now little used but potentially existing wind energy.

The places of windmills indicate the areas where the kinetic energy of the air is sufficient for driving simple mechanisms.

In the areas where there is not sufficient wind energy, animal power was used for driving mills. On the watercourses having sufficient energy there were boat-mills and water-mills.

The large number of windmills once working in the Hungarian Alföld — in connection with the favourable wind conditions — makes probable the possibility that in a considerable part of the area there is enough wind energy to satisfy the small energy requirement of the agricultural co-operatives and detached farms and this can be achieved by putting into operation simple wind-driven power-supplying mechanisms that are already internationally used.

Zusammenfassung: Die geographische Verbreitung der Mühlen, die um die Jahrhundertwende tätig waren und auf offiziellen ungarischen Karten auffindbar sind kann mit den Windverhältnissen in Verbindung gebracht werden. Mit ihr Hilfe kann man es versuchen die heute schon wenig ausgenützte doch potentiell existierende Windenergie zu erforschen.

Zum Antreiben der Mühlen wurde Tierkraft gebraucht in den Gegenden wo es keine genügende Windenergie gibt. Auf den Flüssen mit genügender Energie waren Schiffsmühlen und Wassermühlen zu finden.

Die grosse Zahl der in dem ungarischen Alföld arbeitenden Windmühlen — im Zusammenhang mit günstigen Windverhältnissen — macht die Möglichkeit wahrscheinlich, dass die Windenergie in einem grossen Teil des Gebietes genügend ist zur Befriedigung der Energiebedürfnisse der landwirtschaftlichen Betriebe und der Meiereien, und das kann durch das Inbetriebstellen von international schon gebrauchten einfachen Windtriebwerken erzielt werden.

The effects of the climate are recognizable in any area of the Earth. The properties of the climatice elements are for the most part known, especially their connections with agriculture.

If we choose any climatic element and examine its geographical interactions in the landscape, we obtain interesting results.

In the present paper we undertake to solve a similar task, and within it we examine a part problem, namely the wind conditions and the distribution of the former (one-time) earlier windmills in the Hungarian Alföld.

Wind energy is a constantly renewed natural resource which could play an important part in the energy supply of the Earth. The world energy conference of Rio de Janeiro in 1955 K. A. LEDÁCS, 1956 stated that the kinetic energy of the Earth's atmosphere may be estimated at 6600 billion LE; of this 80 billion LE is utilizable which is forty times the amount of all the water energy supply utilizable. Besides this, investigation of the wind energy is also justified on account of the limitation of the exploitability of non-renewed sources of energy (coal, petroleum, fissile materials).

The cost of production of energy from windpower, if it is used immediately, is one third of the cost of water energy, and requires smaller investments than the water power plants.

Especially in agricultural areas poor in energy sources wind power plants may be very useful by pumping irrigation water, driving small agricultural machines or lighting farms.

The meteorological and technical world literature frequently deals with the need of erecting wind power plants that might work economically. The result of this is that on the international level the Soviet Union, Germany, Great Britain and Denmark have taken the lead in the utilization of wind power.

In Hungary, though utilization of wind power had started earlier, investigations dealing with wind power began only between the 1920's and the 1930's. The meteorological aspect of the question necessitates special investigation, for besides investigation of the territorial distribution of the wind directions and wind velocity the network must be enlarged also vertically as the occurrence of utilizable winds grows considerably with the altitude.

K. A. LEDÁCS (1956, 1958) has dealt with the possibilities of exploiting the wind power in Hungary and concluded that there is no obstacle to utilizing the wind energy up to 22 kW capacity because the world market does already supply ready-made wind power plants with such capacity.

P. Z. SZABÓ (1964), cummarizing the results of earlier investigations confirms the need for investigation of the problem of utilization of wind power.

The distribution of the mills working in Hungary at the beginning of the century is compared in our present paper with the wind conditions in the Hungarian Alföld.

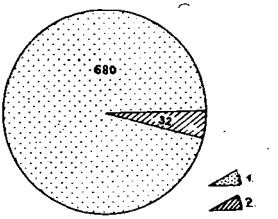
With the creation of agriculture by irrigation and with the development of grain production, the erection of windmills became a necessity. K. A. LEDÁCS (1958) writes in detail about the appearance of windmills and the more important dates of their spread all over the world. For us the Hungarian conditions are important.

The appearance of windmills in Hungary is thought to have occured in the 15 th century. In the second half ot the 17 th century, after the Turkish occupation of Hungary the spread of simple windmills can be taken as a certain fact. Cencerning the period 1811—1815 we have a statistical survey informing us that 8 simple windmills were built in the country.

Most of the windmills were built between 1866 and 1885. The majority of them could be found in the Hungarian Alföld.

K. LAMBRECHT in his series of articles published in the 22 nd volume of

Fig. 1. Territorial distribution of windmills in Hungary in 1894
1 = Alföld; 2 = other territories



Ethnografia, reports the following changes in the number of windmills:

in 1863	475
in 1873	854
in 1885	650
in 1894	712
in 1906	691

As shown in the disc diagram based on the 1894 survey (Fig. 1), 95.5 % of all the windmills in the country were to be found in the Hungarian Alföld.

This also supports our assumption, according to which the Hungarian Alföld has utilizable wind power potential. The existence of such a large number of windmills was closely connected with the grain production of the Alföld, but there were also a large number of horse-driven mills in this area. The distribution of horse-driven mills was generally connected with calm areas.

As the steam turbines and Diesel motors were perfected, the windmills could no longer compete with the steam mills and their number decreased at the beginning of the 20 th century in Hungary too until finally they have disappeared by our days.

Before the introduction of the steam mill, grinding of the grain was done chiefly by windmills and horse-driven mills in the Alföld. Besides cereals corn (maize) and paprika were ground similarly. In hilly or mountainous country the majority of mills were connected with water. There were an insignificant number of water-mills in the Alföld which is natural if we consider the network of watercourses.

The majority of the boat-mills were on the D a n u b e and the T i s z a. Our basic question is where windmills ware or are to be found in the Alföld according to the kinetic energy of the air. If we can correlate the wind conditions with the windmills we will be providing a sort of proof for the fact that according to the calculations of wind frequency there are areas in the Alföld where the wind power would be sufficient to drive mills but and small agricultural machines as well as for electric lighting.

It was in connection with the electrification of farms and the viewpoints of economy that everyday life at the end of the 1940's and the beginning of the 1950's gaverise to the idea utilizing the wind energy. Indeed, there were winddriven electricity-generating installations around Szeged and Hódmező-vásárhely working at the end of the 1950's.

There are only few stations in the Alföld where wind velocity is measured, but wind frequency has been observed for several decades in many places (K. Hegyfoki 1894, R. Wagner 1931).

The existant wind-revording instruments are set up mostly in places sheltered from winds or in places disturbed by wind chirls/eddies; consequently in the evaluation of the data allowance must be made for a percentage of errors.

It is certainly desirable to widen the network of wind velocity measurements in Hungary from the point of view of wind energy research (J. KAKAS—M. MEZŐSI, 1956) which is important also for the Alföld.

Our work is based on 1: 75.000 scale maps of official Hungarian cartographic material. We have delimited the Északi Középhegység (Northern Mountains of Medium Height) according to B. BULLA (1962) as a large morphological unit, because the sheltering effect of the Carpathians can be clearly demonstrated as far as that (G. TÓTH, 1933). We have not been able to obtain homogeneous cartographic material and look through the contem poraneous survey maps, so we have to be satisfied with the fact that the correction of the maps used took place between 1906 and 1920. On the basis of this evidence we have indicated the windand horsedriven mills on the map shown here incluiding the boat — and water-mills too (Fig. 2).

No doubt the wind is strong enough to drive mills in the places where there are windmills. On the other hand, in the places where there are horse-driven mills the wind power is generally insufficient for driving wind-mills.

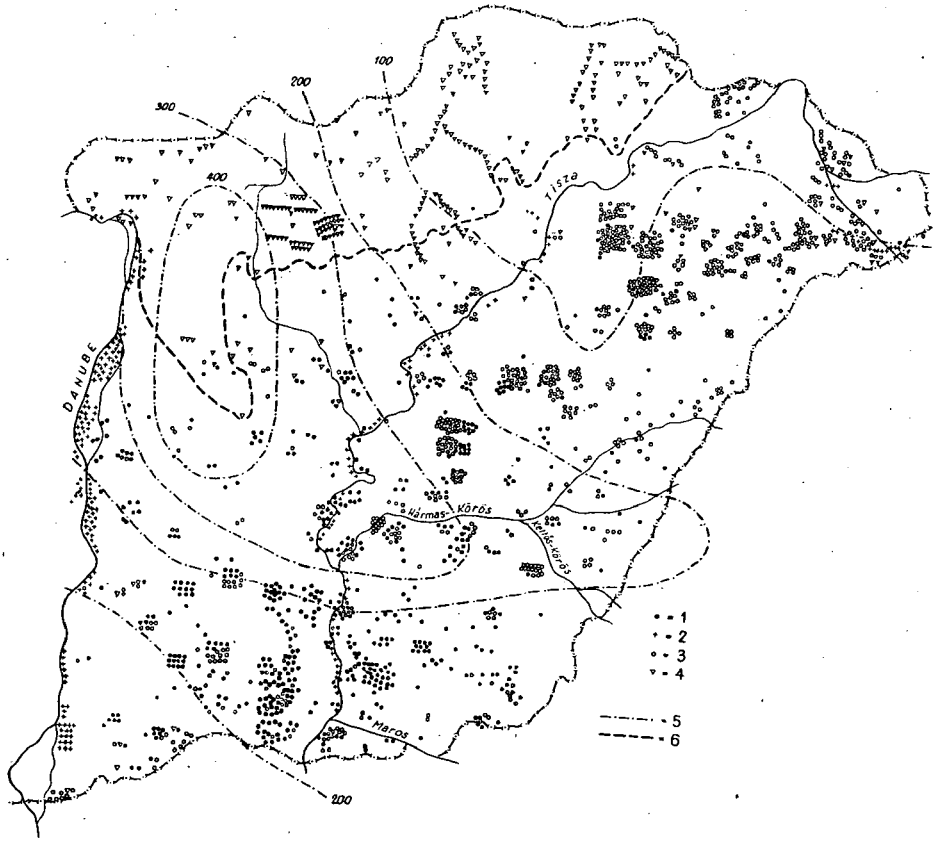


Fig. 2. Geographical distribution of mills and the occurence of calms in the eastern half of Hungary

1=windmill; 2=boat-mill; 3=horse-driven mill; 4=water-mill; 5=occurence of calms; 6=border of the geomorphological area of the Északi Középhegység

Along the rivers there are no windmills or only a small number of them, because in the larger part of the year the more reliable boat-mills used to work here.

The changes of the wind direction and velocity make the work of the mills more difficult or impossible. In mountainous country where the wind velocity is greater water is used for the driving of mills although here, too there is stoppage in winter. Windmills are to be found around settlements, while horse-driven mills in settlements.

We have drawn the wind-mills in the corresponding places of the working map. Owing to the scale of the map sketch, the signs have not always been put in the exact place, but for our purpose they are adequate.

On the basis of these maps we can find 538 windmills and 810 horse-driven mills in the area of the Alföld. These figures, when compared with earlier surveys, can be considered realistic.

After finding the places of windmillis and horse-driven mills compared the maps with the wind conditions of the Alföld. Thus we point out partly the practical importance of the wind calm frequency values, partly we think we can obtain some additional facts for knowing the wind conditions of the Alföld.

The wind conditions of the Alföld with special regard to wind frequency were studied in detail by WAGNER (1931).

The majority of the windmills were located in the southern part of the Alföld. Szeged with its boat-mills was a milling center; in it immediate neighborhood there were only a few windmills, while NE, W, and NW of Szeged, Hódmezővásárhely, Kistelek, Dorozsma and the nearby farms as well as Kiskunhalas, Kiskőrös, Kiskunfélegyháza, Mindszent, Szegvár, Orosháza and its environs are regions rich in windmills. This area has about 70 % of all the windmills of the Alföld.

Away from this area in all directions the number of windmills gradually decreases. Near the M á t r a mountain we find a few windmills here and there only as coriosities.

The largest number of horse-driven mills are to be found east of the river T i s z a, between Debrecen and Szarvas. In the region of the K ö r ö s rivers there are both horse-driven mills and windmills.

The correlation which exists between the wind calm minima and the location of the windmills ceases only in the NE part of the Alföld. There is a definite contrast here between the wind conditions and the distribution of the windmills. In this area, especially in towns with many gardens, windmills were widely used. Investigating only the distribution of the windmills and horse-driven mills one would conclude that the largest calm zone is here in the Alföld.

According to an earlier study by WAGNER this area is windy which is proved also by the sandy regions of N y í r s é g. The greater number of horse-driven mills may be explained by the fact that there are great differences in the annual variation of the prevailing NE and SW wind directions.

The monthly frequency of the wind directions and calms:

	SW	NE	C
Nyíregyháza	16—27	26—37	6—15
Debrecen	17—26	17—23	11—20

This alone would not explain the lack of windmills, but it must also be

taken into consideration that the wind frequency is not in direct relation with the wind velocity. Since the prevailing wind directions in the area are NE and SW, we must suppose that these represent little wind energy in this region and so are not sufficient to drive windmills.

In other parts of the Alföld, especially in its southeastern part (in the region of Szeged), the frequency of calms is in complete agreement with the distribution of windmills.

The greatest frequency of calms with a value of 400 is to be found in the Alföld with Kiskartal and Kecskemét as nuclei. The calm nucleus ranging from Kiskartal to Kecskemét remains always between the Danube and the Tisza. This is connected with the wind-sheltering effect of the Carpathians and the Mátra and Bükk mountains.

The wind-sheltering and deviating effect of the Northern Carpathians was investigated by G. Tóth (1933). He proved with frequency curves of the wind intensity that the middle high range of the Northern Carpathians is an obstacle to the N currents currents going north. It is due to this fact that wind calms are frequent in the northern part of the land between the Danube and the Tisza and in the western territories of the Északi Középhegység. As a consequence in the northern regions of the land between the Danube and the Tisza and horse driven mills are predominant and in the region of the Cserhát and Mátra mountains water-mills.

However, the southern part of the wind calm zone with frequency number 400 comprises also the northern part of the elevated sandy flatland between the Danube and the Tisza. The wind calm zone with frequency number 300 extends also to the territories of the land between the Danube and the Tisza north of Csongrád, Kiskunfélegyháza and Kunszentmiklós and the angle of the Körös.

The wind calm zone with frequency number 200 comprieses the regions of Dunapataj, Kistelek and Békéscsaba. The focus of the windy region is the regions along the Maros and the greater environment of Szeged where the frequency of wind calms is less than 100, and in the town of Szeged itself only 35. The southern boundary of the windy territories in the NE is the line passing through Bodrogköz - Hortobágy-Mezőkövesd.

Indeed, the building of windmills in the region of Szeged seems reasonable on account of the minimum of wind calm frequency. Because of the network of watercourses the conditions of production did not make it necessary to use wind mills in the northern windy territory.

It is surprising that in spite of greater wind frequency there were few horse-driven mills in the northern part of the land between the Danube and the Tisza, while there were also some windmills there. The explanation for this is that horse-driven mills were going out on account of the competition of steam mills, and this territory was not a grain-growing area at the time of the appearance of windmills. The population was mainly engaged in animal husbandry, then later in vine-growing, fruit farming, or truck gardening. In accordance with the requirements of grain grinding, steam mills were built, which led to the disappearance of windmills and horse-driven mills by the beginning of the 1900's. No windmills were to be found around Kecskemét, but there were some in Kiskunfélegyháza. This is explained by the distance from the calm zone, as Kiskunfélegyháza is at the edge of the curve of frequen-

cy number 400. In contrast to what might be expected, horsedriven mills did not prevail in the area and we have no knowledge of any earlier detailed statistical survey.

Besides the the horse-driven mills alone the line of Kunszentmárton—Szarvas—Mezőtúr—Kisújszállás—Karcag—Püspökladány—Nádudvar—Debrecen, especially in the south-eastern section of the line there were windmills. Though their number was smaller than that of the horse-driven mills, it seems that in this area it was necessary to use both types of mills. This is understandable since the maps of monthly calm frequency show that windy and relatively calm months alternate this area. The second half of the year is generally calmer, while the spring and the fall are more windy. The mills used to work here alternately depending on whether the wind power was or was not sufficient for driving the windmills.

The peculiar distribution of horse-driven mills in the windy zone of Debrecen and Nyíregyháza makes it necessary to examine the question more closely.

The spread of horse-driven mills was much earlier than that of windmills. Horse-driven mills were first erected by the Romans, while their existence in Hungary is first mentioned in documents from 1412. Horse-driven mills were most widely used in the 16 th to 18 th centuries. According to LAMBRECHT (1915) the largest number of horse-driven mills in this period were to be found around Kecskemét and Debrecen. In many places in Szeged, too, there were horse-driven mills besides water-mills.

The number of horse-driven mills changed, according to LAMBRECHT (1915), as follows:

in	1863	7966 horse-driven mills
	1873	6361
	1885	3197
	1894	2033
	1906	619

Taking for a basis maps published between 1906 and 1920 we could find 810 horse-driven mills in Hungary. This last number probably includes also the horse-driven mills out of operation.

The windmill did the grinding faster and without animal power and so it soon became widely used in the southern regions of the country according to the wind conditions. In the windy regions of Debrecen and Nyíregyháza, however, horse-driven mills were rather used on account of the periodicity of the wind and therefore their smaller reliability.

Comparing the wind direction frequency values of Szeged, Debrecen and Nyíregyháza we van find no difference that would explain the distribution of windmills and horse-driven mills.

We are led to believe that the wind power is not so favorable in the north-eastern territories of the Alföld as in the region of Szeged.

Working up the data of four years of instrumental observation. J. KAKAS (1947) gave a general picture of the wind direction frequency and wind intensity in our airfields. He classified the wind intensity according to the Beaufort scale and showed the percentile distribution at different stations for the whole year.

With the help of WAGNER's tables (1931) and by calculation we determined the distribution of the wind intensities belonging to the different wind direc-

Table 1.

Distribution of winds of 3th, 4th, and 5th degrees of the Beaufort scale

Station	NE	E	SE	S	SW	W	NW	N	Total
Szeged	43,7	29,7	85,1	133,5	53,2	70,8	135,8	97,7	649,5
Debrecen	154,1	39,8	20,2	12,2	164,7	34,1	27,1	40,3	492,5
Nyíregyháza	250,5	22,5	46,2	26,5	17,8	12,6	25,4	64,9	621,5

tions neglecting winds of an intensity between 0 and 2 and those stronger than 6. (Table 1.)

The talbe shows, on the basis of daily three observations which winds are suitable for driving windmills and how many times if we consider the winds of intensity 3 to 5. According to these data windmills can be used at Szeged on 216 days at Nyíregyháza on 207, and at Debrecen on 164 days of the year. These numbers are sufficient even in the case of the less favourable Debrecen area and do not explain the scarcity of windmills in this region.

Going on we narrow down the range and take into consideration only winds of number 4 to 5 strength according to the Beaufort scale (Table 2).

These data prove the favourable situation of Szeged and its neighborhood. Under the above-mentioned conditions a windmills van work 141 days at Szeged, 120 days at Debrecen, and 128 days at Nyíregyháza.

In the case of Szeged it is also a favourable circumstance that the prevailing wind culminates in July and August. S winds of the second order of frequency are represented from August to December, and the frequency of SE winds increases in the last third of the year. At Nyíregyháza only the SW winds are more frequent in fall and winter. The frequency of calms is greater just in the second half of the year. Largely the same is the situation at Debrecen. Thus, in spite of the first appearance the explanation for the lack of windmills in H a j d ú s á g and N y í r s é g is to be sought in the wind conditions.

The above-mentioned conclusions seem to be supported from another point of view by the monthly means of the wind velocity as recarded in the *Statistics of the Climatological Atlas of Hungary* (1967). The mean values of wind velocity for Szeged between 1958 and 1962 do not sink below 2,6 m/sec even in the less windy summer months, while in the case of Kecskemét or especially Debrecen even means of 2,5 m/sec van be found. The potential possibilities of the exploitation of wind energy in the Alföld are proved also by the direction frequency data of winds of different speeds.

The category of 3,4—5,4 m/sec velocity, which is suitable for driving simple wind power plants, figures in first or second place from the point of vieu of its percentile distribution as compared with other categories.

Table 2.

Distribution of winds of 4th and 5th degrees of the Beaufort scale

Station	NE	E	SE	S	SW	W	NW	N	Total
Szeged	25,7	14,6	54,6	85,6	29,7	47,5	99,5	66,2	423,4
Debrecen	10,2	26,1	21,9	30,8	104,8	22,8	17,9	28,0	359,5
Nyíregyháza	162,6	12,1	20,3	13,6	109,4	5,7	14,5	47,1	385,5

We could not carry out calculations of energy because for that data of special wind measurements would have been necessary.

Summarizing we may say that horse-driven mills, water- and boatmills were used in those regions of the Alföld where there is not sufficient wind power to drive mills; this is why animal power and water power were used here. At the same time windmills mark the places where there is enough wind power to drive mills. Thus the territorial distribution of the mills is connected with the wind conditions. This makes it probable that in the regions where there are windmills the smaller energy demands of the agriculture and the farms could be satisfied with the help of wind power.

Bibliography

Bulla, B. (1962): Magyarország természeti földrajza. Budapest.

Hegyfoky, K. (1894): A szél iránya a magyar szent korona országaiban. Budapest.

Kakas, J. (1947): Repülőtereink széliránygyakorisága. Időjárás *51.*

Kakas, J.—Mezősi, M. (1956): Szélviszonyaink vizsgálata és az országos energiagazdálkodás. Időjárás *60.*

Lambrecht, K. (1915): A malmok könyve. Budapest.

Lambrecht, K. (1911): A magyar szélmalom. Ethnografia *22.*

Ledács, K. A. (1956): Szélenergia — a mezőgazdaság olcsó energiaellátása. Magyar Energiagazdaság *9.*

Ledács, K. A. (1958): A szélenergia hasznosításának története. Energia és Atomtechnika *11.*

Ledács, K. A. (1956): A szélenergia nagyüzemi hasznosítása. Magyar Energiagazdaság *9.*

Magyarország Éghajlati Atlasza (1967). II. kötet. Adattár. Országos Meteorológiai Intézet. Akadémiai Kiadó. Budapest.

Magyarország malomipara 1994-ben (1896). Magyar Statisztikai Közlemények. XIII. Budapest.

Szabó, P. Z. (1964): A szélerő hasznosításának kérdése. Földrajzi Közlemények XII.

Tóth, G. (1933): Az Északi-Kárpátok védő és eltérítő hatása északi szekekkel szemben. Időjárás. *37.*

Wagner, R. (1931): A magyar Alföld szélviszonyai. A szegedi Alföldkutató Bizottság Könyvtára. III. Szakosztály Közleményei. *9.* Szeged.