Coastal Dune Systems on Ukrainian Shores: Modern Tendencies of Development

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Abstract: Coastal dunes are widely spread on sandy shore of the Black Sea within Ukraine. However, their dimensions are small. Usually they look like discontinuos or continuous ridge, 1-2 m high above the beach surface (maximum 5.8 m) and from 10 to 90 m wide in total. In their composition sand with coarseness 0.1-0.25 mm (up to 85%) prevails. The main reason of the small size is prevailing of winds blowing from the Land to the Sea, and original response of the complex landscape structure on sandy form surface to the action of winds of various velocities, directions and durations. 6 scenarios of coastal foredunes development were pointed out, depending on combination: of sediment supply and direction of the resulting vector of wind energy flow. The 6th scenario is the most spread one. According to it there is acute deficit of sediments and the average resulting vector is directed seaward. All scenarioes are described by aeolian drift factor. Space-time peculiarities of the action of aeolian factor and processes, and the character of wind impact to shore dune development are considered. The information obtained is necessary for optimal planning of economic activity, management and development of dune systems in order to preserve them.

Keywords: the Black Sea, accumulative forms, aeolian process, sand, dune, relief, wind

Introduction

During passed decades strong intervention of human activity on the Black Sea coast within Ukraine took place. As a result development of many sites of coastal natural system was disturbed. The fragile system of shore dunes developing in favourable conditions of sediment deficit in coastal zone and prevailing of winds blowing from the Land to the Sea responded most sensitively. In this connection the elaboration of more perfect approach of research and obtaining of additional information on shore dune development whithin Ukraine became necessary. In connection with this actuality of our research is not beyond doubts.

On the other hand application of new methods of investigation and obtaining of more detailed information will allow to make planning of economical activity more perfect, to optimize management and dune system development. These systems are a complex of important ecological shelf for birds, mammals, arthropods, worms and other living organisms. Dunes are located in rest and turistic areas.They are an important element of conservation and sound development of accumulative forms within the Black Sea sandy coast. That is why the theme of this paper is characterized by important practical value.

New data were obtained on correlation between sediment supply in the coastal zone and vector direction of wind energy flow, which allowed to suggest the description of processes of coastal dunes formation by means of aeolian drift. Using the elaborated earlier concept of landscape structure within the sandy accumulative form surface an attempt was taken to understand the process of interaction of winds of various duration and velocity on coastal dunes, spatial-temporal characteristics of aeolian process. Numerical results were obtained by application of methods of stationary research on various sectors of the shore during the action of various wind velocities and directions within the sea beach, dune ridge and limanic zone. The purpose of the paper does not allow to present here all the results. Nevertheless they reflect main conclusions of the investigation fulfilled.

Main scenarioes of shore dune development

Aeolian relief forms are spread practically on all accumulative forms composed by soft sandy sediments. Larger part of sandy forms within Ukraine is situated between the Danube delta in the West and the head of the Karkinit bay in the East (Figure 1), and this region turned out to be the most convenient for our research. Aeolian forms themselves are small, the ones up to 1-2 m high and 30-50 m wide prevail (Figure 2). In fact they represent modern foredune and only in some places, as for instance on distal sides onTendra andjarylgach spits, onTernovka terrace, on the widest sections of barriers, wide belt of low-hummoky relief is developed. Here the height of 1.5-2.0 m is usual, the measured maximum being 5.8 m.Why are aeolian forms on the Black Sea coast small and do not reach such dimensions as on Southern and Eastern shores of the Baltic and North Seas, on the Atlantic coast of France or in South Africa?

Aeolian processes developing in the coastal zone of seas depend essentially on two main groups of factors: sediment supply and wind characteristics (ZENKOVICH, 1967). Depending on the combination of these factors, favourable and infavourable conditions for aeolian process development are formed. Other can indirectly strengthen or weaken the action of the given two main factors, they are height and density of vegetation cover, relief of sandy accumulative forms and indigenous land adjacent to them, coarseness and humidity of sediments, etc.

Taking into consideration wide and various information on aeolian processes on the World Ocean shores it became possible to elaborate and formulate several scenarioes of shore dune development depending on combination of drift supply values and the direction of the vector of wind energy flow.

Scenario 1: In the coastal zone there are a lot of sediments, and the resultative average flow of wind energy is directed from Sea to Land. With such combination favourable conditions for appearing and augmentation of dunes are formed, progressive increasing of their size and sand mass takes place.

Scenario 2: In the coastal zone there are lot a sediments and the resultative flow of wind energy is directed along the shoreline in general. Such conditions are also favourable for appearing and augmentation of dunes, but in general their dimensions turn out to be a bit smaller and the local migration of sand is more prominently expressed.

Scenario 3: In the coastal zone there are a lot of sandy sediments, the resultative flow of wind energy is directed from Land to Sea. In such conditions often there are no big dunes sizes, usually they represent a broad and low sand ridge.The foredune is the highest, but its height is less than in two previous scenarioes.

Scenario 4: In the coastal zone there are few sediments and resultative wind energy flow is directed from Sea to Land. With such combination the formation of low dunes usually takes place, their displacement landward, as in Scenario 1 is often clearly expressed, the dune belt width is greater than in Scenarioes 2 and 3.

Scenario 5: In the coastal zone there are few sediments and the resultative wind energy flow is directed along the shoreline. In such conditions the formation of shore dunes is not always possible, most often it takes place on very wide spits and barriers with steadily dense vegetation. Dune size is essentially smaller than that in scenarioes 1,2 and 4.

Scenario 6: In the coastal zone there are few sediments and the resultative wind energy flow is directed from Land to Sea.This combination is the least favourable, under its influence the formation of dunes is most often impossible. Even if shore dunes appear they represent separated embrional forms of small size.

The scenarioes given above consider primary principally important conditions of formation and development of dunes, the regime of their development, changes in time being controlled by such factors as the width of accumulative forms, dismemberness of the coastal relief, density and height of vegetation, composition and humidity of sediments, etc.

Determining the aeolian drift coefficient

In conditions of development of narrow and low barriers and spits on sandy shores of the Black Sea within Ukraine, the area of spreading, configuration and discontinuity of aeolian relief are determined by the correlation of volume (real amount of sand) of aeolian shifts in directions from the Land M, and from the Sea *M* sectors of the horizon. This correlation aeolian drift coefficient K_{m_l} we suggest calling.The summary amount of drifting sand in composition of motions from the Sea and from the Land both separately can be different depending on the conditions in accordance with scenarioes 1-6. If the amount of sand in shifts from the Sea and from the Land is the same, the aeolian drift coefficient will equal 1, i.e. *K,* = M, / M = *I.*

If under the influence of physic-geographical conditions the amount of the transported sand turns out to be greater from the Land than from the Sea, the coefficient of aeolian drift will be greater than 1.The larger is the variable M_l, the greater is *K„* which means growth of the importance of sand transportation from the Land, and more and more unfavourable conditions for appearing and formation of shore dunes. And vice versa: the increase of the value of AÍ variable conditions the decrease of the coefficient *K* . to less than unity with constant M_l, the reduction of the importance of sea winds, formation of favourable conditions for appearing and development of shore dunes as shown by corresponding scenarioes. Absolute numerical values of M_l and M are also of great importance: higher values are more favourable than low even with *K* , = Í.The most favourable conditions will be formed when the values of the variables are maximum and the difference (M - M_l) is maximum, if the structure of underlying surface of accumulative forms is favourable for sand accretion.

It is necessary to state what is the criterium of the concepts *"Utile sand"* or *"much sand".* In this paper as well as in other ones (SHUISKY and oth., 1989,1992;VYKHOVANETS, 1995) under "much sand" it is understood that in the coastal zone during long-term period stable accumulation on the nearshore bottom and beach takes place, and the shoreline moves seaward. And vice versa "little sand" means the situation when during a long period the nearshore bottom and beach are steadily eroded and the shoreline retreats landward. In general "few" or "many" sediments seem to be relative, because absolute numerical values can be different within different alongshore lithodynamical cells or separate sites of the coastal zone. It is evident that such interpretation is universal applicable not only while studying aeolian processes but other coastal processes as well.

For instance, if we compare sandy shores of the Black Sea within Ukraine and southern sandy shore of the Baltic Sea within Poland we can see that sediment deficit prevails in both regions. Both in Ukraine and Poland destructive processes are dominating (SHUISKY, VYKHOVANETS, 1989; SUBOTOWICZ, 1994). However on the Baltic Sea sandy drift supply is an order larger, though the wave regime is more severe; accumulative forms (for instance,Vistula and Hel spits, Leba barrier) are wider and higher. This is explained by an order of value larger specific supply of sandy drifts to the coastal zone of the Baltic Sea in comparison with the Black Sea. Such difference is determined mainly by higher numerical value of positive elements of sedimentary material balance. That is why the volume of alongshore drift flow along the southern Baltic Sea coasts reaches hundreds thousands mVycar, and even more while in the studied region of the Black Sea the maximum constitutes only 325,000 mVyear.The given considerations emphasize once again that aeolian process is one of the components of complex exogenous processes in the coastal zone, it is closely connected with all other processes.

Peculiarities of wind influence on shore dunes

Let us consider display of each of the sccnarioes to the shores of the Black Sea within Ukraine. It is necessary to point out at once that scenarioes 1, 4 and 5 are not typical for the studied region between the Danube delta andTarkhankut cape the wind energy flow from the Land to the Sea is resultative (Figure 3). At the same time the prevailing number of the authors from other countries give the results of aeolian process study in conditions when winds from the Sea prevail in the average a long-term period.

Tcrnovka terrace surface can serve as one of the examples of aeolian relief development according to the scheme of scenario 2. It is situated on the junction of the nothern part of Dniestrovskaya barrier with the indigenous dead cliff of 25 m high. Its length equals 3 km, the width varies from profile to profile from 70 to 300 m. Here the shoreline is oriented along the compass azimuth NE : 36".That is why the terrace is essentially protected by the high cliff against the action of strong and frequently reoccurring nothern and north-western winds, and therefore is situated in the wind shade during the action of these directions. That is why that main relief-forming role is played basically by alongshore NE and E, and to a lesser extent SW winds. Since early 60s of this century regular stationary measurements stated progressive movement of the shoreline seaward along the terrace.Thus, only during 1981-1995 the average width of the terrace increased by 59 m (from 49 to 10« m), and sediment volume *(F)* to the 1 m depth by 267 nrVm (from 53 to 320 m An) (Figure 4). Growth of terrace width favoured the development of aeolian relief forms as the wind distance length over the sandy surface increased accordingly. During the same period the width of aeolian dune belt grew by 74 m (from

16 to 91 m), the height by 1.1 m (from 2.2 to 3.3 in), the volume of aeolian sediment by 163 mVm (from 31 to 194 mVm). The situation described here is generally typical on those sectors of the shore where scenario 2 acts.

Development of aeolian relief according to scenario 3 is typical for the sectors of unloading of alongshore sediment flow, for instance in Jebriyan harbour, on distal sides of Tendrá and Southern Kefalnaya spits. Jebriyan spit and adjacent on north-eastern direction terrace in Jebriyan harbour are the most illustrative (Figure l). The terrace and spit are situated along the base of low (up to 3 m high) dead cliff which does not prevent the action of winds from various horizon sides, in contrast to the sector where Ternovka terrace is located. The analysis of maps published during last 150 years, as well as of the data of natural stationary measurements during last 30 years showed that intensive accretion of sediments takes place here. The rate of shoreline increase changes within wide limits, from 1.4 m/year along the sea front part of the terrace to 30 m/year on the distal point of Jebriyan spit (SHUISKY.VYKHOVANETS, 1989). However, inspite of quick accretion of sandy sediments, aeolian forms are characterized by supressed appearence, small embrional forms are widely represented. And only under the screen of dense vegetation, especially bushes, discontinuous and continuous ridges were formed, 1-2 m above the zero-water level. On the whole the sandy relief is hummocky with distincdy pronounced wave ridges (Figure 2). Their height above the average sea level is not larger than 1.3-1.5 m, which corresponds to the height of surf flow motion during storms (gales). Calculation of aeolian accumulation coefficient *K.* for several sectors of Jebriyan harbour showed that its value varies from 1.75 to 2.83. This means the steady blowing off of sand into the Sea in the average 1.75-2.83 times more than comes from beach to Land. The similar situation was observed along the marine south-western margin of Tendra spit distal side. On it the aeolian drift coefficient varies from 1.76 to 3.26, which will be taken into consideration lower while analysing spacial changing of aeolian process.

The evolution of foredunes by scenario 6 is the most spread on Ukrainian shores, in contrast to many shores of other seas. This scenario is generally typical for all barriers and spits excluding the majority of distal sides of spits. On the studied shores of the Black Sea the width of coastal accumulative forms as rule varies from 40 to 490 m, however values 60-200 m prevail. During last 150 years shoreline of barriers and spits undergoes continuous reterat with the average rates from 0.1 to 4.8 m/year. Therefore such quick retreat continuously supports the decrease of width of barriers and spits, and first of all of the beach which is not covered by vegetation (SCHUJSKIJ and oth., 1992). That is why the momentum distance of wind flow over the sand surface is constantly decreasing and the part of the area covered with vegetation is increasing. In conditions of sediment deficit and absolute prevailing of winds from land side to sea direction the mechanism of scenario 6 leads to extremely unfavourable conditions of appearing and existance of shore dunes. This complex of reasons explains why the size of dunes is not large along the majority of sandy accumulative forms in the Black Sea coastal zone.

Landscape structure of accumulative forms surface

On the crossing profiles of barriers, bars, spits, and often terraces as well, three landscape-morphological zones (longitudinal belts) are distinctly displayed: marine, aeolian and limanic (VYKHOVANETS, 1995).

The marine zone occupies the belt of maximum surfing wash of the biggest stormy waves and in fact is a sea beach.That is why the width in the majority of sectors has constant values equalling 25-35 m and only in places where pads and offsets are spread it can reach 40-50 m. Usually its height corresponds to the height of the surf blow wash of the biggest stormy waves and is not larger than 1.5 m. In its limits marine hydrological factors mainly waves and wave currents act as the leading relief-forming factors.

The limanic zone is the widest one. Within this low, wet and solted belt the width varies from point to point from 5-10 m to 100-200 m.Wave cones (fanes) of sand overwashed by stormy waves from sea beach are often met. The wider is the spit, barrier or bar, the wider is the limanic zone. On the sectors with minimal width of accumulative forms (up to 50-60 m) the typical limanic zone is absent. Limanic hydrological factors are the basic relief-forming factors, aeolian factor has the subjected importance. Vegetation bioturbation processes, migration of solt solutions and other non-hydrological phenomena play a big role. Most often the surface of the limanic zone is 0.1-0.8 m higher than the average zero-level water of liman (lagoon, bay), which leads to frequent occurrence of swamped area.

Aeolian zone serves as the connecting link between the marine and limanic zones. It is the highest one on the surface of accumulative forms (Figure 2). Its height constitutes from 1.5 to 3.6 m (maximum 5.8 m),the width being from 10 to 90 m, sometimes wider. Aeolian relief-forming processes are the leading ones. As a rule, shore dunes are situated as discontinuous or continuous ridges in the form of distinctly pronounced crest. Where the width of barrier or spit exceeds 200-250 m, short lower crest or irregularly scattered aeolian hillocks, 0.5-1.0 m high are situated behind the foredune ridge. Everywhere the foredune is higher than the other aeolian forms, it is the result of accretion of sand transported from all sides of the horizon. Aeolian movement of sand under the influence of winds blowing from sea landward leads to the conservation of sediments in the limanic zone for a long period and in the aeolian zone for a short period. And seaward winds cause blowing ofFof sandy drifts from aeolian belt and from sea beach to the Sea.The difference between them constitutes the value of aeolian accumulation.

As it is known (HORIKAWA, 1988; ZENKOVICH, 1967), wind is the main moving factor of aeolian process development. All other factors, forming landscale structure within accumulative form surface euther slow down or transform the wind action (vegetation, relief parting, composition and humidity of sediments, etc). They favour the general decrease of transporting ability of wind. If we compare its value in directions to the Sea, to the Land and across barriers or spits, it will be different during the action of the same wind parameters and due to complex landscape structure.

The sea beach is a source of sediments for aeolian forms during the wind blowing landward. According to the data by K.HORIKAWA (1988), the wind flow with the speed approximately 10 m/sec reaches saturation by sediments when it passes the distance longer than 10 m above the sandy surface starting from the line of wind influence, sand humidity being < 3%. On the Black Sea shores during the calm period the beach width is usually 25-35 m.The movement of sand with average diameter d = 0.1-0.2 mm starts with the wind velocity 4.5 m/sec and mass transportation is carried out by velocities exceeding 10 m/sec, if the sand is dry.

With the increase of the landward wind velocity, size of wind waves grows and the set up level is rising. The greater the wind speed and wave size, the higher the storm-surge. That is why up to 70% and sometimes more of the beach width are flooded by sea water (VYKHOVANETS, 1995). Accordingly, the width of the dry beach decreases as well as the distance of wind momentum above the sand surface, therefore the source of sediments runs short. Therefore, however paradoxically it looks, but the increase of the wind velocity from the Sea to the Land lead to the decrease of transported sand amount. The lesser is its quantity coming to the aeolian and limanic zones.

When the wind blows from the Land partially aeolian zone and the whole sea beach are the source of sediments.Their width in sum constitutes not less than 50-60 m. Such length of wind flow momentum is sufficient for saturation of wind-sandy flow.The increase of wind speed leads to the increase of moving sand amount.

The second important factor of aeolian process development in conditions of complex landscape structure of accumulative forms is the time of wind-stable surface formation. This factor is determined by granulometric composition and humidity of sediments, thickness of dry sediment layer on the beach, content of shell and shelly detritus. Without going into details, let us note that formation of wind-stable surface of the beach occurs more quickly during the action of landward winds than during the seaward ones. That is why landward winds lead to quicker running short of sediment source. As a result, the wind action of the same speed and duration caused blowing of sediments into the Sea from the surface of accumulative forms more intensively and during a shorter period in comparison with the process of compensating supplay of sand. If we take into account that on the studied sandy shores of the Black Sea seaward winds blowing prevail, then in average during a long-term period during not less than 8 months sand blowing off to the Sea prevail. Correspondingly during 4 months, basically in May-August, sand drift off on the accumulative form prevails, but at this time winds of mainly low velocity act.The amount of sand within wind-sandy flow is 2-3 times less, than from September till April (Figure 5 a,b). As a result the average annual vector is directed to the Sea and it supports all the time small size of aeolian forms. In general the aeolian drift coefficient varies from 1.37 to 2.20.

Correlation of space and time in aeolian process development

Modern aeolian processes within the coastal zone are characterized by spacial (along the shoreline) and temporal inhomogeneousness (HORIKAWA, 1988; SHUISKY.VYKHOVANETS, 1989; ZENKOVICH, 1967).This inhomogeneousness is conditioned by variability of characteristics and parameters of the factors influencing the wind-sandy flow development. The analysis of the wind observation data during a long-term period on the Black Sea sandy shores showed that the given characteristics and parameters have rhythmicity. It is expressed in regular reoccurence of prevailing directions, duration and velocities of wind in some time intervals (OSINSKAYA, 1971,1972a). Atmospheric rhythms can be of several orders: stormy, seasonal, annual, long-term (many years), intersecular, secular (SHUISKY, 1976). Like the wind regime other factors influencing the formation of wind-sandy flow, as, for instance precipitations, temperature regime, dencity and height of vegetation cover, etc. are also subjected to rhythmiciry.

In the average for a long-term period in the coastal zone between the Danube delta and Tarkhankut cape seaward wind of NW, N and NE directions prevail (Figure 3). However, in some seasons and years essential deviations from the average long-term direction of wind vector are possible. In interannual section of time the highest reoccurrence of strong winds is typical from November till March including repeatedness, duration, velocity and direction of winds are determining for aeolian process development, and they undergo essential changes depending on severity of winter on the whole or of separate months from November till March.

During winter months of *"severe type"* and in March, October and November of year with the winter of "severe type", wind regime differs in the respect that wind flow from the Land to the Sea more often than usually, and from the Sea to the Land more rarely (HYDROMETEOROLOGY..., 1991). In comparison with the months of *"soft type"* years, during severe winter months repeatedness of nothern wind (20% against 12%) on the shores between the Danube delta and the head of Karkinit bay, and of north-eastern wind (23% against 11%) along the shoreline of Karkinit bay and western Crimea is especially heightened. "Severe winters" on the studied coast are observed with the interval from 1 to 16 years, but most often from 3 to 6 years.The growth of wind repeatedness of southern half-bearings and decrease of repeatedness on north, north-eastern and north-western ones is a peculiarity of winter months, the late autumn and early spring during the winter of "soft (warm) tipc". Winters of'soft type" occur every 1-9 years, but most often every 2-3 years.

Abnormally cold and abnormally warm months and seasons differ not only by the parameters of air temperature, velocity, duration and direction of winds, but also by variability of other meteorological elements, for instance precipitation. They are not less important in the process of aeolian relief formation. It was found out (HYDROMETEOROLOGY..., 1991; OSINSKAYA, 1971, 1972b), that during winter months of "severe type" precipitations occur somewhat more rarely than in winter of'soft type".The quantity of precipitation can also be lower.

The given peculiarities of weather-climatic situation to a great extent determine modern changes of aeolian processes in time.

According to the stated above, the calculation of volume (capacity) of wind-sandy flow by the data of a long-term period showed that wind conditions for aeolian processes develop best of all in winter, in late autumn, and early spring, if accumulative forms are not covered with snow, as in winter 1995/1996 for example. Taking into account rhythmicity of natural conditions deviation of direction and cubic content of aeolian drift from long-term trends should be expected. It is evident that during the years of very severe winter from October till March conditions for the formation of shore dunes will be particularly unfavourable. Frequent and strong winds, simultaneously with relative dryness during cold year period will evacuate sand from aeolian zone surface and from the sea beach to the Sea. In addition direction of this process can be strengthened by other factors influencing wind-sandy flow, in particular by steepness of beach surface, area and height of vegetative cover, beach width.

During winter-spring period of'soft type winter" opposite situation is formed. Landward winds prevail, but duration of action and velocity are essentially smaller than of the same period winds of "severe type winter". That is why aeolian sand drift landward will be smaller. Higher amount of atmospheric precipitation reduces aeolian movement. That is why all other conditions being equal, during the years of "soft weather type" winter motion of sand landward will be smaller, in comparison with the amount of sand moving seaward during "severe weather type" winter. Such phenomenon reduces the extent of dune-forming wind impact and increases the action of dune-destroying winds. As a result dunes on the sandy shores of the Black Sea cannot reach essential size, conditions of sand evacuation and preservation of their small height are supported.

In addition to temporal changeability aeolian processes are subjected to variations from point to point (spacial). Such changeability in conditioned by variation along the shore of those parameters and factors which form wind-sandy flow. The most essential factors are: exposition of the shore line in relation to these or those directions of the winds during different seasons, prevailing of this or that scenario of aeolian process development, different composition and supply of sediments, different width of sandy accumulative forms, etc. They are different along the shores of such complex composition, as between the Danube delta and Tarkhankut cape in general, which causes spacial difference of aeolian processes and forms. And, if on each of relatively homogeneous sectors rhythmiciry of the development of wind regime, temperature and humidity is superimposed, it can be imagined how wide the spectrum of spacial differentiation of aeolian processes is.

Complex interaction of all factors forming wind-sandy flow leads to its corresponding variability. Volume and direction are the main characteristics (Figure 5). They are different on shore sectors with different exposition. Unfortunately, such interaction has been poorly dealt with in geographical literature, and if it is considered, it is done in the most general way.

As example 5 sites characterized by the average monthly values of wind-sandy flow volume seaward (+ FJ and landward (- $F_{v,}$) are given. Their algebraic sum DF_w is shown on the diagrams of Figure 5 a and b. Calculations allowed to see clearly that resultant shifts of sand seaward prevail absolutely. On the chosen sites in different points of between the Danube delta and Tarkhankut cape values $+F_{m(}$ usually correspond 60-70% in the average during a long-term period (Figure 5 a), on Kinburn and part of Tendra spits +F act practically all year round. Sometimes this phenomenon is displayed in 50-55%. Sand evacuation into the Sea is particularly intensive during the period from October till April and on the prevailing majority of accumulative forms (Figure 1). According to the explanation given above, such direction of the drift reflects peculiarities of wind regime, landscape structure of spit, bar and barrier surface and exposition of the shoreline within various lie— hodynamical cells and sites.

At the same time, influence of the complex contour of the shoreline with different exposition on the direction of resultative drift DF in conditions of relatively homogeneous wind field can be illustrative (Figure 5 b). Sites under observation are situated on the distal side of Tendra spit (Figure 5 c). Points 1-4 on the diagram are the points denoting the lines on the diagram of Figure 5 b. Here E, N and NE wind directions prevail (in the sum 43%), the share of strong winds with the velocity higher than 15 m/sec being 4.7%, i.e. 2.75 times more than with the remaining 5 directions. Correspondingly, sector 1 faces prevailing winds and the main part of sand (about 85%) is carried on the Land (Figure 5 b, *1).* But for sector 2 prevailing winds are partially sea ones, and therefore sand drift to the Sea somewhat increases, though sand drift to the Land still prevails. The share of the resultative evacuation of sand constitutes about 24% seaward. On sector 3 the shore line is strongly curved and the direction of the rcsultative drift DF . changes to the opposite: sand is evacuated to the Sea in 63% of causes in the average for a long-term period, the average monthly values DF' being minimal from May till September, as on other sectors (Figure 5 b, 3). The shore line continue to curve in south-eastern direction, and the tendency of resultative sand drift to the Sea increases. On sector 4 the evacuation to the Sea is maximal and equals 69% in the average for a long-term period, the average monthly values DF , being negative during the whole year (Figure 5 b, *4).*

Thus, the direction of sand motion under the impact of wind is steadily influenced not only by wind regime, as it was shown above, but by the complexity of the shoreline contour. On the distal side ofTendra spit on some sectors one and the same wind can be a landward one, on other sectors is a seaward one.Taking into consideration landscape structure and underlying surface of accumulative form numerical values of aeolian drift (+ *PJ)* and (- FJ can also vary, which correspondingly influences the relative drift DF , Such phenomena determine territorial (spacial) distribution and size of aeolian shore forms and peculiarities of their development.

Conclusion

During a few last years there were publications about aeolian processes and shore dunes on the Black Sea sandy coast within Ukraine, reflecting the results od long-term stationary and natural experimental investigations (SCHUJSKIJ und oth., 1992;VYKHOVANETS, 1995). They were dedicated to the determination of numerical values of aeolian drift impact of vegetation, sediment composition, relief, general landscape structure on aeolian process. In this paper main attention is paid to the role of wind and shoreline exposition in the development of coastal dunes. On the basis of the use of these factors 6 basic scenarioes of aeolian process development described by aeolian drift coefficient *K* , were suggested. Increase of the coefficient above 1 shows the prevailing aeolian drift to the Sea, and the decrease below 1 points to the prevailing sand movement landward. Landscape composition on accumulative form surface determines numerical values of factual amount of sand transported by wind on all cases wind is an active moving factor of aeolian drift, and underlying accumulative form surface is a showing down factor retaining and transforming sand movement and reducing numerical values of the drift.

Within the studied shore of the Black Sea between the Danube delta andTarkhankut cape seaward winds acting prevail.They create the general background of aeolian evacuation of sand from the Land to the Sea. However, during seasons of year and years with different weather severity the general regularity is broken, which gives the opportunity for development to greater number of scenarioes of shore dune formation during this or that year. That is why modern spacial and temporal development of aeolian processes is characterized not only by physical-geographical local conditions of different shore sites, but by certain rhythmicity of wind regime as on the sandy shores of other seas. At the same time during years with different severity of winter under the influence of concrete relative homogeneous wind field conditions of shore dune formation can be different. They are conditioned mainly by the complexity of contour and different exposition of the shore line along the short distance interval. This regularity was analyzed on the typical example of the distal side ofTendra spit.

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