Elżbieta Wołk-Musiał

MORPHOMETRY OF THE BALTIC GLACIATION RELIEF AND ITS LEGIBILITY IN AERIAL PHOTOGRAPHS

Relief of a terrain is defined by morphometric parameters whose knowledge is indispensable to identify types of relief available and trace the origin of the particular forms. Such parameters include, among other things, hilliness, orientation of longer axes in convex forms, layout and number of depressions having no outlet and the rate of dismemberment of an area, understood as the density of erosional dissection. These have been analysed in the aerial photograph on the scale of approximately 1 : 16 000, whereas findings obtained in such a way served as a basis for comparisons with the results worked out on the grounds of a topographic map of 1 : 25 000 scale.

The problem so outlined was tried to be solved by exemplary reference made to the land situated to the north of Ełk, whose relief is linked with the process of deglaciation of the Baltic continental glacier (Bogacki, 1976; Galon, Roszko,1967; Kondracki, 1978). The area under study covered 150 square kilometres (Fig. 1).

The study began with the analysis, on the grounds of a 1 : 25 000 topographic map, of morphometric features of the relief for the whole area under examination, to allow one to identify in such a manner types of the existing relief. Subsequently, an attempt was made to correlate types of the relief with the satellite imagery on the scale of 1 : 500 000 magnified to the scale of 1 : 200 000. The area under study has been interpreted in three MSS channels with spectral intervals of 500—600 nm, 600—700 nm and 800—1100 nm. Photostructural units as spotted according to satellite imagery generally remain in agreement with the identified types of relief, and only „bottoms of the river valleys and depressions with no outflow" as well as „planes by the lakes" failed to be distinguishable in a satellite imagery due to their tiny forms.

Panchromatic aerial photography built up into two sets so as to cover the entire area under study, differing both in their scales and quality, constituted basically the material for starting the subject.

"The eastern set of photographs" reaching the line of Rydzewo--Konieczki (Fig. 1) was made on 28th August, 1970 on the scale 1 : 16 320 and was characterized by good contrast. "The western set" on the other hand, which was taken on 28th August, 1970 and embraced most of the area under study on the scale of 1 : 16 410, consisted of photographs that were grey in their tone and included little-diversified phototones. It is no doubt therefore that also the possibility of interpretation in both these sets varied to a certain extent. To investigate the problem, densitometric analysis has been applied to the profile spotted in the negative of the more and less contrasty photographs, the latter being referred to further on in the text as soft negative. The profile in question is cutting the western part of Lake Przytulskie into two and has been chosen so to embrace within its reach the greatest possible acreage of farm land.

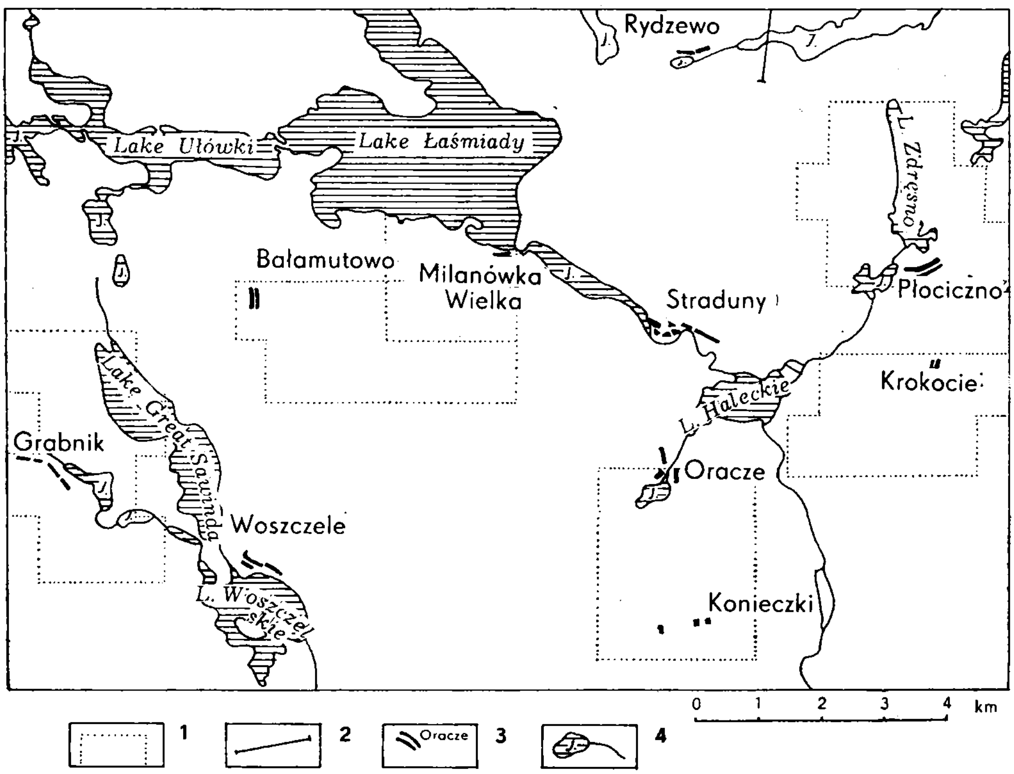

Fig. 1. Planimetric map of the site under study
1. Test areas; 2. Line of the densitometric profile; 3. Localities; 4. Rivers and lakes.

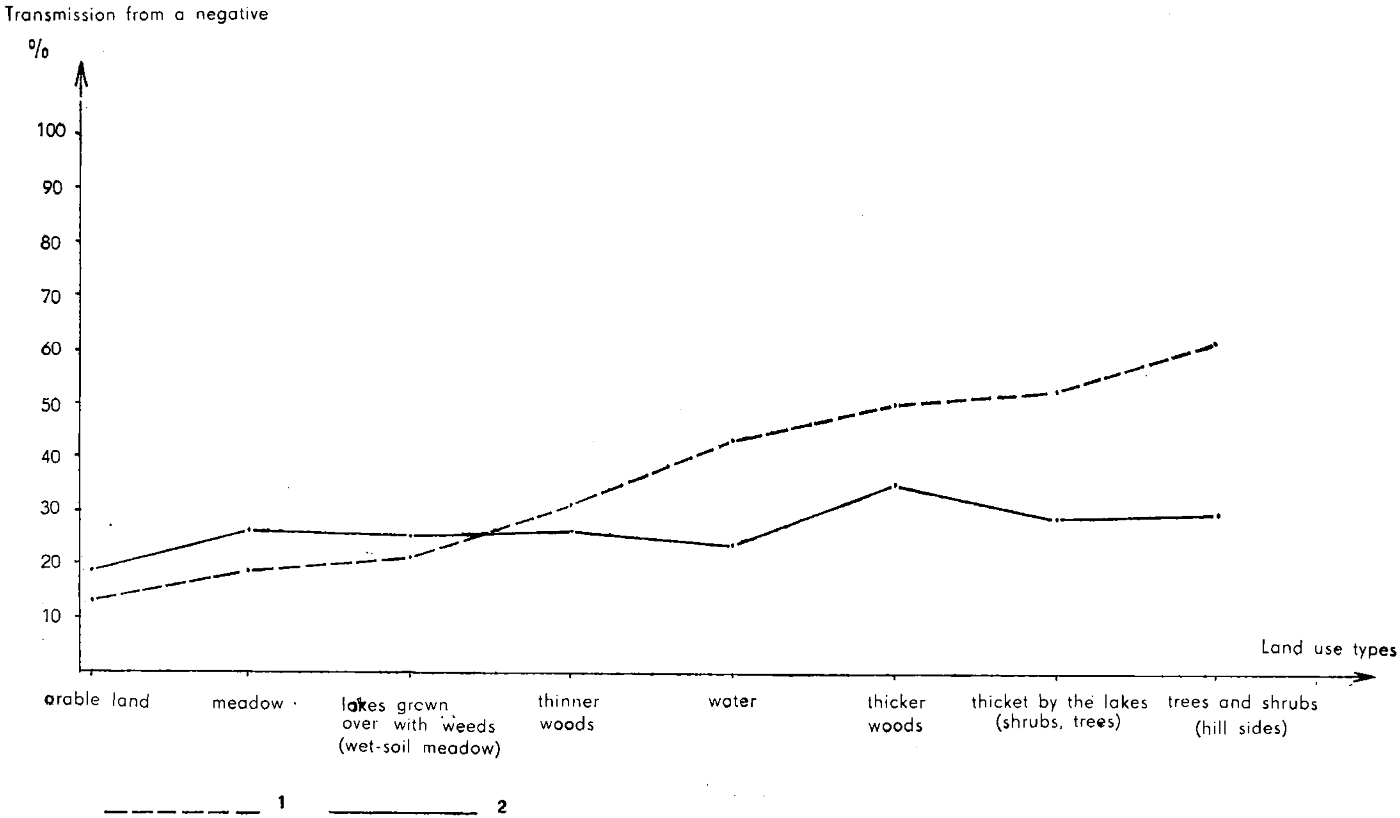

Fig. 2. Averaged variations in the spectral brightness of land (negative) according to its good-contrast negative; soft negative; arable land; meadow; lakes grown over with weeds (wet-soil meadow); thinner wood; water; thicker woods thicket by the lakes (shrubs, trees); trees and shrubs (hill sides); transmission from a negative, land use types.

Differences in the brightness of various pieces of farm land, depending on the quality of negative, have been shown in Fig. 2. It is possible to say on the grounds of Fig. 2 that transmission difference in the case of a good-contrast negative ranges from 12 to 55 per cent whereas in soft negatives it will be no more than 19 to 24.5 per cent. Accordingly, it will be also much easier to discern phototones and to spot details in a photograph with a better contrast. A certain convergence is clearly evident in this case, notably, the 6—20-per-cent transmission of a good--contrast negative corresponds to an increase in the values obtained from a 12—26-per-cent soft negative, whereas the 30—61.5-per-cent values of a good-contrast negative are matched by lowered figures of the 26—32-per-cent- soft negative.

Thus, differences in the quality of photographic material for the two aforementioned sets of photographs are remarkable indeed and this will bear heavily on the possibility of interpretation in the study of the early-glacial relief.

The analysis of the morphometric parameters to learn the relief was started by describing first the hilliness, i.e. the rate of concentration of the hilly forms, within a unit equal to 1 square kilometre in area. Such a small size of the reference area has been adopted because of the small-hillied character of the early glacial relief. This feature has been studied against panchromatic aerial photography on the scale of 1 : 16 410 for two chosen fragments of the area in which the feature under consideration is occurring with maximum or minimum rate of intensity. These are found south of Lake Łasmiady (Bałamutowo). and east of Lake Haleckie (Krokocie). The number of hills was assessed by referring to the same basic grid cells both in the aerial photographs and in the topographic map of the 1 : 25 000 scale.

However, before discussing findings of the two aforementioned research materials it would be necessary to investigate some of the facts.

A topographic map on the scale of 1 : 25 000 is reliable enough to discern details of the relief with an accuracy not exceeding 2.5 metres and this accuracy has been generally stable for the whole of the area under consideration. Things however are different, when the same problem is approached from the viewpoint of aerial photography. With a good-contrast photograph and a diversified grid of phototones it will be possible to distinguish hills smaller even than 2.5 metres in height (relative height). But it was also often so, as for instance in the case of a fragment of territory south of Lake Łasmiady (Bałamutowo), that difficulties were encountered in spotting the convex forms. The relief of this area is characterized by the occurrence of a number of vast depressions communicating with each other by way of peat-bogged valleys. This causes that the grey phototone starts to dominate in a photograph due to an increased humidity of soils and the existence of meadows and pasture land. It is by no means a rare experience when small hills occur inside the depressions and by representing pasture land lend grey phototones to the aerial photography. Where poor contrast becomes yet another drawback of aerial photography for such an area, lack of stereoscopic vision may be the result in the event of small forms which otherwise are easily spottable on a topographic map. A similar situation prevails on the terrains with bright phototones, but there are also territories which give high diversification of tones in aeral photography whereby greater number of hills can be discerned in the latter case as compared with the topographic maps.

A comparative analysis of the number of convex forms in the area south of Lake Łasmiady, built primarily of boulder clay, has shown that the aerial photography and topographic map data generally resemble each other. Deviations in relation to cartographic material tend to range from -6 to $+7$ and are broadly due to factors described above. There are only two basic grid cells in which much of the area is a woodland masking relief of air-photography with the effect that error in the number of hills spotted goes higher. In the terrains surrounding the village of Czerwonka thirty hills could be „read" on the map as against only nine discernible from a panchromatic aerial photograph. At the same time, the investigation of the two most eastern squares of this series gave 31 to 38 convex forms on the topographic map as against only 22 to 30 such forms in aerial photography.

The smallest number of hills per one square kilometre as found according to a 1 : 25 000 topographic map appears east of Lake Haleckie (Krokocie) and ranges between 9 and 16. This region is built of sands and gravels, aqueous and glacial in their origin. Convex forms in aerial photographs embodying the same grid cells as topographic map come quite clear in the terrains having no wood cover. Aerial material for such a territory gives good contrast which causes that even the smallest hills, hardly distinguishable on a map because of contour lines exceeding 2.5 metres grading, become discernible. Broadly speaking, the number of convex forms for woodless regions remains somewhat higher than this could be found from a topographic map and ranges between 9 and 23. Apart from differences in the phototones, this can also be due to variations in land uses. All the convex forms, even the smallest hills at the bottoms of vast depressions like e.g. those in the grid cell south-east of the village of Krokocie, represent a cultivated land. This produces their bright phototone in aerial photography, as compared with the darker tone of the depressions, and raises "legibility" of convex forms even those which are less than 2.5 metres in relative height. Reconnaissance of hills from aerial photographs in a wooded land is of course less effective, which is especially true for the grid cell right eastwards of Lake Haleckie. From the topographic map nine hills have been identified, as against only two discerned by means of a panchromatic aerial photography, as having a convex form.

While summing up it would be wise to say that the comparative analysis of the number of convex forms from aerial photography and topographic map has given generally close results for both terrains with the maximum and with the minimum intensity of the feature. The clearly different geological formation of the two areas under study (clay and sand) has had little effect on the number of convex forms identifiable by means of an aerial photography. Much more essential proves to be the manner in which the land is used, as it tends to mask convex forms in the poor-contrast photographs and simultaneously helps to identify them in the good-quality ones. The least satisfactory is the identification of hills from aerial photography when the land is covered with woods.

Related right to the hilliness is the issue of orientation of the longer axes in the convex forms. It has been investigated for the same areas for which also hilliness was an object of studies.

The problem of "reading" from aerial photography what the direction of morphological centre line of a hill proves to be is linked directly with the possibility of identifying the form itself. In a topographic map, convex forms are clearly visible and the defining on the direction in which the longer axes follow presents no difficulties. Some problems, on the other hand, may arise while identifying a hill on the grounds of an aerial photograph. Things will get still worse when yet morphological axis of such a hill is to be found, as with a poor stereoscopic effect a change in its sense seems to be truly unavoidable. Quality of aerial photography has much to say in such a case.

Things will be different when dealing with areas having a maximum and minimum number of convex forms per one square kilometre.

For the test area situated eastwards of Lake Łasmiady (Bałamutowo) the highest compatibility of the sense of directions as identified according to aerial photograph and topographic map will show basic grid cell north-eastwards of the village of Czerwonka. NE — SW and NW — SE are two directions chiefly identifiable in this case. The remaining basic grid cells of this series differ in their data as furnished by air-photography and topographic mapping. Basic grid cells of the southern series exhibit somewhat greater compatibility of directions, except for the area including the village of Czerwonka where most of the basic cell is taken by wood. NE-SW and NW-SE are basically the most frequent directions represented in this case, similarly as those in the upper series.

While analysing the possibility of identifying the direction of longer centre lines in convex forms for areas with a minimum number of hills per 1 square kilometre, it will be necessary to emphasize that a much greater compatibility exists generally between the aerial photography and topographic map data. Photographic material for these areas is of a good quality (good contrast), and the relatively rare hills offer a much better chance of properly identifying the sense of their direction. Some inaccuracies may happen when a larger number of convex forms is to be read from an aerial photograph, or when the areas under study are covered with woods.

To sum up the subject one might say that much more accuracy and speed are expected when hills are identified for the sense of direction of their longer axes from a topographic map, in particular in those cases where aerial photography coverage exhibits a poor contrast.

A comparative analysis of identifying depressions with no outlet within a grid cell of 1 square kilometre in actual area, from a topographic map on the scale of 1 : 25 000 and from a panchromatic aerial photograph on the scale of 1 : 16 410, was carried out for the areas in which the feature under study is occurring with a maximum or minimum intensity.

One of the fragments of the test area is found southwards of Lake Łasmiady (Malinówka Wielka) and is characteristic of the minimum number of depressions observed in 1 square kilometre. Another one, south of Lake Wityny (Konieczki), presents a number of depressions at maximum intensity.

As in the interpretation of hilliness, also in this case the preliminary notes have their validity while applying to the depressions which have not an outflow. In the topographic map depressions are shown with the depth of 2.5 metres at least. In aerial photography, on the other hand, the possibility of spotting depressions depends also on the quality of the photographic material and fails to be constant for the whole of the area under consideration. If the distribution of phototones is favourable, a far greater number of depressions with no outlet will be identifiable for some fragments of the area, even at a depth of less than

2.5 metres than it would be the case with a topographic map. There are, however, also such fragments in which depressions deeper than 2.5 metres will be hardly visible.

While analysing identifiability of depressions with no outlet from panchromatic aerial photography on the scale of 1 : 16 410 and from the 1 : 25 000 topographic map for an area south of Lake Łasmiady (Malinówka Wielka) an increase is found in the number of depressions as identified according to the photographic source. Five to eight depressions per square kilometre could have been "read" from the photograph, whereas the topographic map offered for the same fragment of the land a density of only one to three depressions per one square kilometre. This increase in the value obtained from photography is due to a relatively good contrast of the aerial source. Depressions with no outflow contain a higher percentage of moisture and are marked by a darker phototone in the photography. Should they additionally appear on a brighter background, which is normally connected with the particular type of land use and indirectly also with the type of subsoil involved, then it will be comparatively easy to discern even those depressions which are less than 2.5 metres in depth.

Things prove to be a little different in those regions where the feature under consideration is at its maximum intensity (Konieczki). Aerial photography for this area stands out for its poor contrast which makes it that the number of depressions with no outlet in a 1 km^2 grid cell is reduced. And only in those places where the phototone is getting patchy, as e.g. southwards of the State Farm Wityny, more depressions (nine) than in the topographic map (six) are identifiable. It must be, however, stressed that not all the identifiable dark patches denote depressions. They sometimes appear in the slopes of convex forms, being most probably connected with another type of vegetation, and their phototone comes a little brighter than that which is characteristic of the moist depressions having no outlet.

On the whole, however, depressions with less than 2.5 metres in depth are rather difficult to identify because of the poor contrast of aerial photography throughout the area and shrubby vegetation covering some of the larger depressions devoid of outlet. From the topographic map, 6 to 19 depressions having on outlet could have been discerned per 1 square kilometre, whereas from a panchromatic aerial photograph only 2 to 12.

In conclusion it may be said that the number of identifiable depressions primarily depends on the quality of aerial photography and on the extent to which the land is covered with woods.

The possibility of "reading" from aerial photography the density with which the site under study has been cut by valleys, of which density is understood as a length of the valley-network in kilometres over a 1 km^2 mapping unit, will be presented on the grounds of two study areas: the neighbourhood of Lake Zdręsno and the terrain west of Lake Sawinda Wielka. The length of valleys has been invetigated in the same basic grid cells for which it was studied from the topographic map of the 1 : 25 000 scale.

The sites as mentioned above have an air-photography cover varying in its quality. Photographs of Lake Zdręsno surroundings have good contrast, whereas poor quality of the photographic material from Lake Sawinda Wielka district renders interpretation highly questionable.

For the Lake Zdręsno test area, the compatibility in the interpretation of the morphometric feature under study is equally good be it panchromatic aerial photography or the topographic map. It is only basic grid cell of the central series eastwards of Lake Zdręsno that provides a higher value for the length of the valley-network in the event of aerial photography. The difference in the latter case is 1.3 km/km^2 and may be due to a more diversified relief of this territory which contains a great number of convex forms with some small dry valleys present among them. This causes high variability of phototones to the effect that both the course of valleys and the assessment of their lengths can be observed with ease with the aid of a stereoscope.

Things are different while studying the same phenomenon for the area situated west of Lake Sawinda Wielka. The analysis has been carried out on the poor-contrast photographs and this adversely affected final results. Only in three basic grid cells aerial photography data and the topographic map data were approximately the same. In the grid cell north-west of Lake Sawinda Wielka there even went up the length of valleys as measured from the aerial photographic material. Grid cell under investigation, in spite of the fact that analysed using poor-contrast photography, stands out for high variability of its phototones (as compared with other photographs of the same set) and this favourably affected stereoscopy and accuracy in identifying the length of valleys.

As regards other basic grid cells, they exhibit a marked reduction in the value of readings got from aerial photography as against those from the topographic map. One reason is the presence of woods which practically make the interpretation of relief impossible. Similarly, the area enclosed by the basic grid cell south of Lake Szeneczk gives smaller values of readings for the parameter under study from the air-photography, although the site has no vegetable cover. This is a farm land where the narrow strips of fields producing little-diversified phototones (photography with poorer contrast) adjoin the lake basin. It is possible that these regular geometrical forms and the unidirectional configuration of fields mask the system of dry valleys present in this region.

While summing up it may be said that the good-contrast panchromatic aerial photography on the scale of 1 : 16 410 is good enough to ensure the interpretation of a parameter showing to which extent the land under investigation has been cut by valleys. It is sometimes, however, the case that some of more dry valleys appear well-marked in the aerographic source and then the value of readings comes higher than in a topographic map.

In poor-contrast photography, on the other hand, the legibility of land covered by valleys is much lower. This applies in particular to the territories having a wood cover and to all those sites where the specific arrangement of fields masks forms under investigation.

While summing up the analysis of morphometric parameters as carried out to identify the relief of the site under investigation from aerial photography and the topographic map, it must be emphasized that compatibility of results has been chiefly due to differences observed in the quality of photographic material. In good-contrast photograph, morphometric features are generally marked better, and the results of interpretation are convergent with those obtained from a topographic map. Where photographs with a poorer contrast have been analysed, differences between the two sources of information, i.e. photograph and map proved to be much greater. This was clearly evident while analysing such features as the density of erosional dissection and orientation of the longer axes in convex forms. In such cases, the topographic map appeared to be a more reliable source of information.

Some consideration should also be given to the scales of source material available. The scale of aerial photographs is approximately 1 : : 16 000 and that of topographic map 1 : 25 000. This difference alone may give rise to certain variations in the number of details distinguishable. The map is on a smaller scale and that is why a certain generalization has been employed in this case according to 1970 Instructions. The aerial photograph, on the other hand, presents the image of land relief as it is exactly in reality or at least tends to do so. The possibility of its interpretation accordingly depends on the quality of a photograph, being a primary condition for getting a good stereoscopic effect for investigation.

REFERENCES

B o g a c k i, M., *Współczesne sandry na przedpolu Skeidararjökull (Islandia) i plejstoceńskie sandry w Polsce północno-wschodniej* (Contemporary Outwash in the Foreland of Skeidararjökull, (Iceland) and the Pleistocene Outwash in the Nort-Eastern Poland), Warsaw University, Warszawa 1976.

G a l o n, R., R o s z k o, L., *Zasięgi zlodowaceń skandynawskich i ich stadiów recesyjnych na obszarze Polski* (The Extent of Scandinavian Glaciations and their Recession Stages within the Polish Territory), PWN, Warszawa 1967.

Instrukcja do sporządzania szczegółowej mapy topograficznej w skalach 1 : 100 000, 1 : 500 000, 1 : 25 000; (Instructions for Drawing Detailed Topographical Maps on the Scales of 1 : 100 000, 1 : 50 000, 1 : 25 000), MON, Warszawa 1980.

K o n d r a c k i, J., *Geografia Fizyczna Polski* (Physical Geography of Poland) PWN, Warszawa 1978.