Jan R. Olędzki

INTERPRETATION OF SOME GEOGRAPHICAL ELEMENTS ON THE BASIS OF LANDSAT-1 MSS IMAGES

Although the remote-sensing techniques have advanced a great deal over the recent years, it is still very difficult to provide an effective processing and utilization of data supplied from the boards of satellites and aircraft. Difficulties encountered result from the mere fact that progress made in the techniques of acquiring imagery of the Earth remains far ahead of the possibilities of interpreting such data. It is not so easy to link the new remote-sensing techniques with the traditional research methods of centuries-long standing and with the long-established cognitive experience into one research system. Appropriate studies are under way to investigate land areas specially chosen for this purpose and to work out on their basis adequate methods of interpretation for the satellite imagery available.

By comparing spatial differentiation of the geographical environmental elements with their image obtainable through various remote-sensing techniques a solution is sought to the problem in that possibly reliable photointerpretation methods might be worked out so as to ensure a fairly high dependability of the geographical data.

In the desire of taking a realistic approach to the problem of indentifiability with regard to elements forming part of Poland's geographical environment in the satellite imagery transmitted via the way of LANDSAT, a fragment of Central Poland has been analysed and assessed in one of its parts. Subscenery under investigation covered remote-sensing test grounds of Płock where surveying was carried out in 1978. The following physico-geographical units formed part of the subscenery: (Fig. 1) the northern part of the Kutno Plain, the eastern part of the Kujawy Lake District, the Płock Basin, western part of the Płońsk Upland, the Płock Upland, and southern part of the Lake Dobrzyń District (Galon, 1972, Kondracki, 1978). Differences revealed in the geographical environment proved highly helpful in assessing, with a high degree of probability, to what extent the presentation of various environmental elements on LANDSAT satellite images could be found as reliable.

The analysis itself was carried out by scanning optically the black-and-white multispectral material taken on a scale of 1 : 250 000 by the LANDSAT-1 (ERTS-1) satellite on November 2nd, 1973.

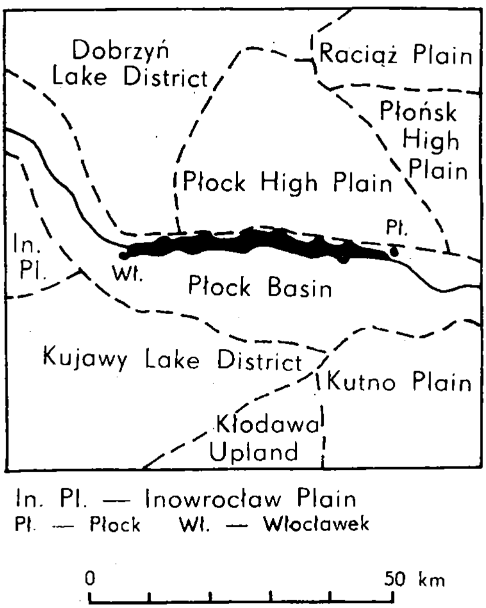

Fig. 1: Physico-geographical division of the subscenery under investigation

GEOLOGICAL CONSIDERATIONS

Geology of the investigated subscenery shows, in fact, little differentiation. Formations present therein represent in their bulk predominantly loose Quaternary deposits of the most different kind (Geological Map 1948).

The valley of the Vistula River occupies central part of the subscenery (Fig. 2). Sands and boulders from glacial accumulation (a) form the main part of it. They show in many places signs of intensive aeolian processes. Depressions in this area are accompanied by peats, alluvial soils and river sands building up the lowermost terrace of the Vistula. Their somewhat darker appearance in the satellite imagery comes from the coniferous forests covering, almost entirely, the whole of

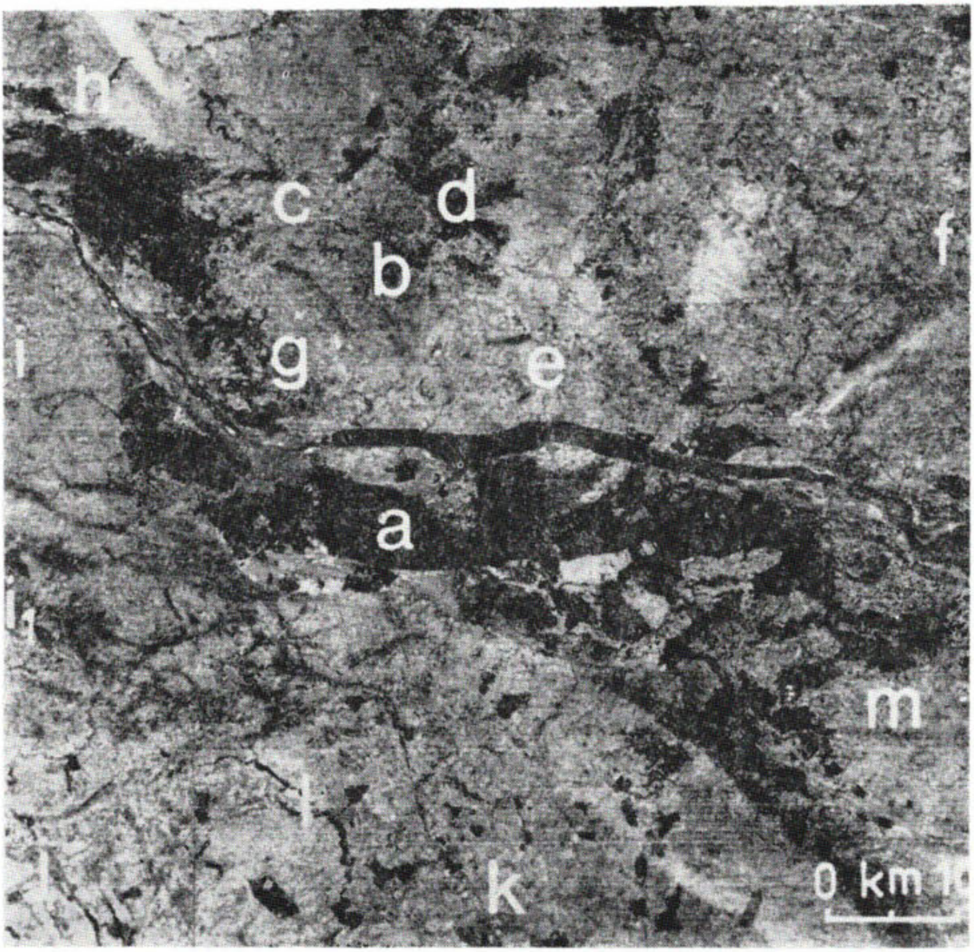

Fig. 2: Fragment of the MSS-7 satellite image. Letters correspond to the geological formations.

the afore-mentioned geological formations. Brighter spots have been identified as concentrations of the sand dunes. Hence, the character of this part of the image derives from close relationship existing between vegatation of this place and its geological formations, i.e. sands.

Alluvial soils, sands and peats occur near the river bed, and the phototone in such a case is much brighter compared with the woodland fragments. Formations of that type, if combined with the specific relief of the land i.e. valley, virtually represent the only, well-defined, fragment of the satellite imagery, to which certain lithological forms may be ascribed.

North and south of the Vistula River valley, relationship between the phototone and lithology ceases to be so clear and distinct. Nonetheless, north of the Vistula River valley one can distinguish several areas which differ in their phototone as well as in the texture of the image. One of such areas is situated north of Włocławek (b), built in its mass of the glacial-accumulations sands resting on the boulder clays. These formations remain closely linked with two or three recessions or oscillations of the Baltic glacier as it was with drawing in the north-western direction (the Leszno Substage of Glaciation). Compared with the site surrounding it, this area is clearly darker in phototone on all the MSS images.

When proceeding in the eastern direction, the phototone is getting darker in a few places identified as woodland areas (d). These areas contain a relatively true representation of bundaries within which there are outwash sands and gravels that had been accumulated during the Kujawy deglaciation phase of the Poznań Substage.

South and east of this region there are sandy deposits and sands mixed with boulders, and this has found its expression in the relatively brighter phototone (e).

The eastern part of this region is characterized, on the other hand, by a somewhat darker phototone. This may, to some extent, be also due to the fact that sands occurring in this place overlay boulder clays. Another distinctive feature of this region is a little different texture the image of grid of the well-developed and shaped river valleys, dendritic in their origin, exhibits. Here we enter already the area of the Płońsk Upland being a little outside the reach of the Baltic Glaciation phenomenon.

To single out geological units, well-defined in the categories of photographic specification, would be yet more intricate when moving to the south of the Vistula River valley. In principle, the whole of this area looks similar on the image. It will be only west of Włocławek that one will be able to reveal the shade of the phototone getting clearly darker (i), as seen from the MSS-5 image. According to findings from the analysis of geological map, this region is primarily built of boulder clays.

The southern part of the subscenery looks definitely brighter. The western fragment of the land (j) includes mossaic pattern of the sandy, clayey and peaty formations padding out bottoms of the relatively wide valleys. Eastwards. the image is getting a little brighter (l). Records of this area point to a greater share of the boulder clays, historically linked with the frontally-morainic accumulation of the Poznań Substage of Glaciation.

Further eastwards, there follows an increase in the participation of sandy, clayey and peaty formations of the valleys, (k—m). The phototone in this place is getting darker again.

Images taken in various channels of MSS, when compared with each other, lead to the conclusion that one is in a position to distinguish with their aid, in a general outline, complexes of geological formations if only such formations are dominating over the study area. Accordingly, the phototone is getting darker when forests represent land cover overlying sands and boulders as well as outwash sands and gravels. Sands are lying on clays, and the latter have a relatively dark phototone. Sandy formations and sands mixed with boulders are comparatively bright in their phototones. MSS images of peats occuring in the valleys are, as a rule, dark in channels 4 and 5 and brighter in channels 6 and 7.

It would be, however, difficult to assess relationships stated above as univocal. These are rather tendencies than rules. Differences observed in phototones are fairly small and call for a rather individualistic approach to the problem, especially if we agree that each phototone remains an outcome of more than one, superimposing and interweaving, image of the geographical environmental components. It would be equally useless to try to overestimate or underestimate any of the four electromagnetic spectral intervals produced in the MSS system. It however comes true that the greatest differences in the optical spectra of each geological formation are observed in the MSS channel 4 and 5 images.

HYDROLOGY

Hydrological situation in the region under investigation remains associated with its chief morphological features. The central part is accentuated by the Vistula River valley in which terrace-like levels with dunes have evolved in quite a lot of places. North of the Vistula River valley, and south of it, most of the land is ground moraine and only some tiny fragments carry terminal moraines and outwash material on top of them.

With such a poorly developed land relief it would be rather useless to expect any greater differences in the hydrological context and, in particular, in the occurrence of the first-level subterranean waters. The first level of subterranean waters occurs throughout the entire area covered by the ground moraine two to five metres deep, and its yearly oscillations do not exceed three metres (Hydrogeological Map 1960). In some places, and this refers to the valley bottoms (lake basins and terrace levels, in particular), the first water-bearing level is likely to be shallower.

The largest areas containing shallow subterranean waters at a depth of no more than zero to two metres are the Vistula River valley (d), valley of the Rakutówka River and the Lake Rakutowskie basin (e), as well as valleys of the rivers Sludwia and Ochania (f) (Fig. 3). Those areas, like many other smaller ones which happen to occur within the ground and terminal moraine limits find their expression in somewhat darker tone on satellite image MSS 5 and 6, as compared with the neighbouring land. On images in channels MSS 6 and 7 the same areas

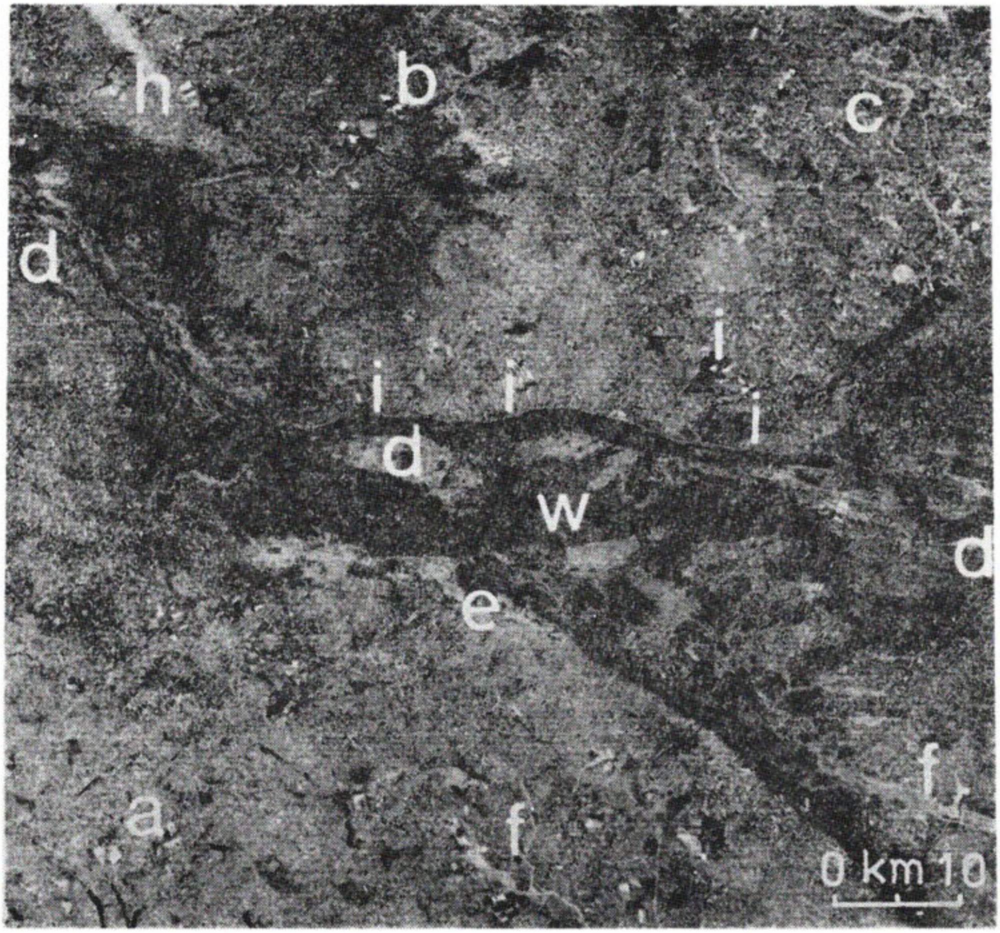

Fig. 3: Fragment of the MSS-5 satellite image. Letters correspond to the first level of underground waters.

are clearly brighter in their phototone and this will be fully understandable, if we take into account the season of the year during which images were taken and spectral intervals of 500 to 700 nm in the first case and 800 to 1100 nm in the other.

Areas with the first level of underground waters situated a little deeper are characteristic of those places in which the terminal moraine formations (h) show a tendency towards spreading, as e.g. in the case north of Włocławek fringe zones of the Vistula and Skrwa River valleys and some surface areas of the ground moraine between Kutno and Żychlin. In these areas, underground waters occur at depths exceeding five metres, sometimes even more than twenty metres. On satellite images however, it is, not so easy to distinguish any clear-cut relationship existing between such waters and the visual effect such areas can furnish when recorded on the MSS scanner imagery. An exception to this is the terminal moraine (h), north of Lipno, which in its northern part appears totally different on the satellite imagery taken in all spectral ranges, compared with the neighbouring areas, in its phototone.

To sum up, the relationship between images recorded in various electromagnetic spectral levels and hydrological situation of the site proves negligible enough or hardly noticeable under conditions when the first level of the subterranean waters is below two metres. It will be in the case of the shallow-fond underground waters only, above all in the river valleys, that on the basis of visual analysis of the imagery, and imagery recorded on channel MSS-5 (dark phototone) and on channel MSS-7 (bright phototone) in particular, one will be in a position to identify every area in which the level of subterranean waters will be at a depth of less than two metres. As regards the remaining intervals of depth at which subterranean waters are likely to occur, they will hardly find any reflection in the satellite imagery under investigation.

Things look hardly better in the case of hydrographical surface elements and possibility of their interpretation. Swamps and marshy grounds, although they occupy an area of one per cent, are practically unidentifiable. Mater-courses are hard to identify, too. In black-and-white photography no more than three per cent of the hydrographic network was distinguishable. Well identifiable, on the other hand, appear to be the surface water reservoirs and also the Vistula River among them. The latter occupies 2.5 per cent of the acreage under study, and compared with the topographic map on the scale of 1 : 100 000 identifiability of such reservoirs comes at 100 per cent.

SOILS

In the subscenery under investigation there are chiefly grey-brown podsolic soils, leached brown soils, and the topgleyed soils, the so-called pseudogleys. These occupy nearly two thirds of the total acreage (Soils Map, 1872). They are dependent on the underlying parent rock and in their occurrence they are more or less related to the spatial variation of geological formations present in this area. In the north--eastern part of the scenery, nearer to the Vistula River, dominant are soils made up of a powdered matter varying in its origins as well as soils built up of the driftsand and light boulder clays. The latter are noticeable in the north-western corner of the scenery. In the southern part of it a spatial split is observed in the said soils, and in the eastern direction differences in the soils are increasing. Clays in this region are formed of the medium-and heavy-weight boulder clays, driftsands, light boulder clays, and the poor-clayey sands, whereas west of the Kutno-Gostynin line there predominate soils built of driftsands and light-weight boulder clays. Scenery in which the said soils prevail stands out for the presence of a generally medium-grey phototone.

In contrast to the relatively uniform medium-grey colouration of the background there are also areas of the land having rust-coloured soils and podsolic soils, formed of loose sands and podsols, and these areas are comparatively distinctive in their contours. They occur in the Vistula River valley, on higher terraces, and are distinguishable on satellite imagery by a somewhat darker phototone of woods growing in these areas.

Noteworthy is the relatively clear relationship existing between contours of the above-mentioned soil areas and boundaries of the dark--phototone woodland acreage. This may be assumed as evidence of a direct relationship, in some areas at least, existing between the type of geological formations and soils present and the characteristic flora. In areas other than woodland, and this applies to terrains north of the Vistula River in particular, the presence of rust-coloured ils is emphasized by a somewhat brighter phototone of the image in all four spectral ranges.

Darker spots varying in their intensity according to spectral range applied can be distingusihed as contrasting with the uniformly grey phototone of the background. These spots rather accurately fit the areas of black and grey meadow soils that developed on clays and silts varying in their origins.

In the subscenery under investigation relatively distinctive come areas containing hyrdromorphic soils which, as a rule, fill out depres-

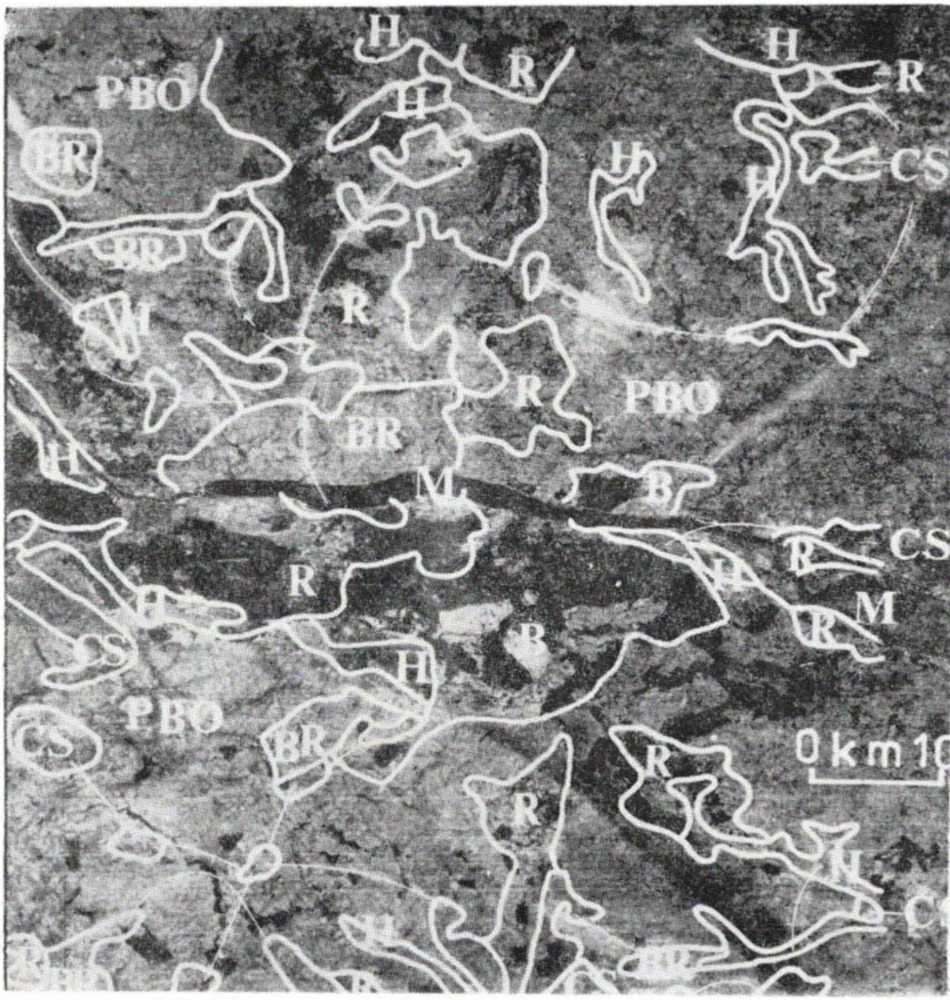

Fig. 4: Fragment of the MSS-5 sateilite image with boundaries of the chief soils as per the 1 : 500 000 Poland's Map for Soils duly marked thereon

B.R. Typical brown soils and leached brown soils, P.B.O. Grey-brown podsolic soils (alfisols); brown leached soils, pseudogleys, B. Podsolic soils and podsols. R. rust-coloured and podsolic soils, C.C. Black and grey meadow soils, degraded, M. Alluvial soils. H. Hydromorphic soils.

sions of the larger valleys and lakes. Peats padding bottoms of the valleys form an envelope of peaty soils which appear darker on the images in channels MSS 4 and 5 and much brighter in the other two channels MSS 6 and 7.

The analysis made leads to the following conclusions:

From among soils identified within the limits of the subscenery, more or less independent in all MSS channels proves to be the image of the black and grey meadow soils found in the Kujawy Region. Well contoured are also areas with the predominantly hydromorphic soils, i.e. marshy peat soils associated with the valley-type depressions, river valleys and lake basins. Their image remains an outcome of the overall geological, morphological and hydrological situation, causing a relatively univocal delineation of each of the specified natural environment elements in their contouring.

The extent to which the said types of soil go according to the satellite imagery is specified much more accurately than this might result from the Poland's Soil Map made on the scale of 1 : 500 000. From other soils, and this will apply to the rust-coloured soils and podsolic soils and podsols formed of loose sands in particular, identification is possible to follow indirectly through the vegetable attire, woodland more specifically, covering the area.

LAND COVER ELEMENTS

To determine the extent to which satellite imagery can be found useful in the assessment of the state of geographical environment, each of the four MSS images taken in various spectral ranges has been visually analysed for the dinstinguishability of relevant land cover elements. In the process of the analysis we could identify such elements, as forests, surface waters, farm land, meadows, and human settlements. Also linear elements, such as rivers and railway, could have been spotted. Figure 5 is a resultant composition of the images that have been analysed.

The percentage of the respective elements and their acreage as distinguished from satellite images differs, as seen from Table 1. Woodland areas seem to be easiest to identify. Comparison of the percentage of woodland as found from the MSS-5 satellite imagery with that obtainable from statistical data (Statistical Yearbook, 1977) exhibits high degree of compatibility. Data from the 1 : 100 000 map prove to be a little lower, which is quite normal if we take into account the lapse of time between the dates of map preparation and satellite image.

Surface waters as an element not easily liable to changes in time are excellent in assessing the usefulness of satellite images for the purpose of inventorying the stock of open-surface waters. The percentage of surface water acreage is approximately the same for image sources and the map.

Farm land which occupies more than seventy per cent of the area is the dominant element. Its acreage when determined by satellite images generally comes higher by a few or even more per cent. This

Table 1

Utilities	Percentage*				
	Map 1 : 100 000	MSS-4	MSS-5	MSS-6	MSS-7
Forests (woodland)	12.4	18.7	19.6	18.4	14.3
Surface waters	2.1	2.2	2.3	2.5	2.5
Individual farm land	74.3	79.1	77.7	76.2	79.9
	—	—	—	0.6	1.0
Meadows	5.3	—	—	2.8	3.6
Swamps	1.2	—	—	—	—
Barren land	0,2	—	—	—	—
Settlements (resid. quarters)	4,.5	0.0	0.4	0.1	0.7

* Percentage of the particular utilities in the land cover; information furnished according to various sources.

remains closely linked with the fact that farm land acreage usually embraces also smaller meadows, urbanized areas and even smaller towns, extremely hard to distinguish and represent cartographically.

Advantageous in the analysis of satellite image proves to be, however, the fact that large-area forming complexes can be identified, and these occupy about one per cent of the total land. The rate of distinguishability in the case of meadows is fifty per cent. Swamps and barren land are practically unidentifiable.

Residential areas distinguishable in the channel MSS-7 image and representing approximately sixteen per cent of the total acreage occupied by human settlements and towns according to the 1 : 100 000 map correspond, in principle, to the largest urban centres of this region, such as Płock, Włocławek, Lipno, Sierpc plus some smaller localities and certain villages.

Things go much worse if one wants to identify linear elements on the satellite images. Compared to a topographic map, only 12.6 per cent of the water courses and 12.2 per cent of the railway lines are identifiable. Completely unidentifiable is the network of all kinds of roads.

CONCLUSIONS

To sum up, satellite image analysed over an area of approximately 5,500 square kilometres is a very good example in assessing recordability of data concerning geographical environment in Central Poland.

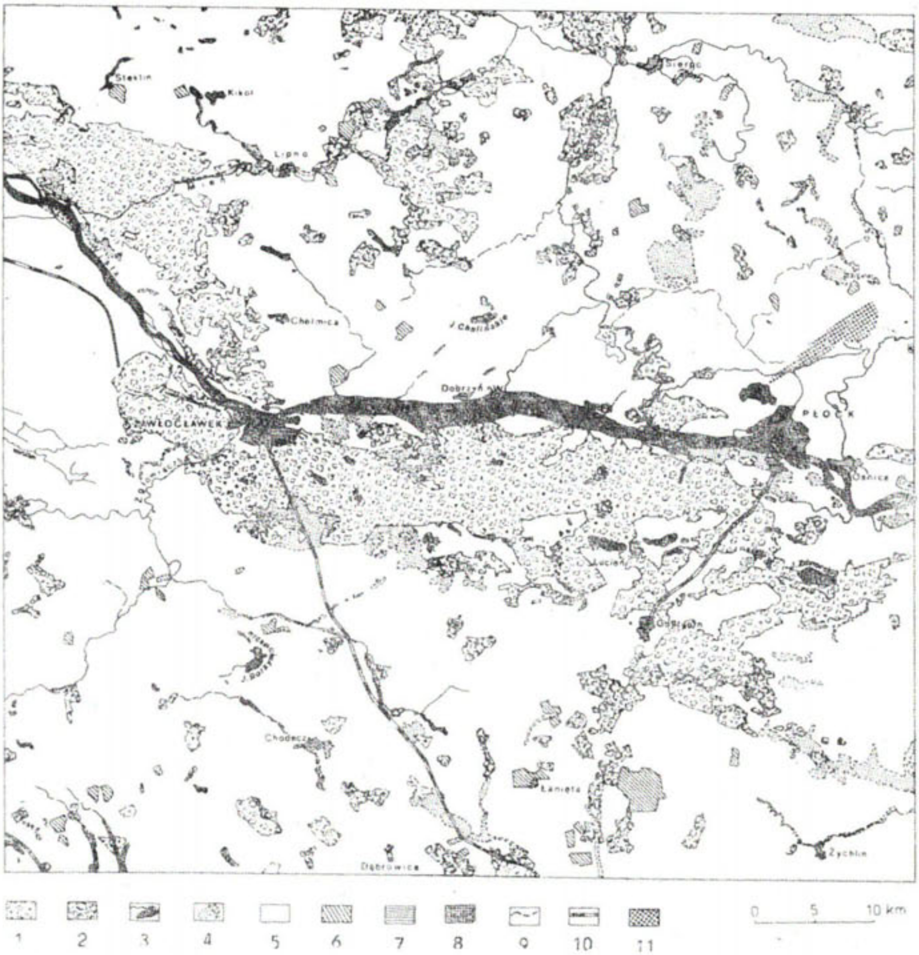

Fig. 5: Interpretative Map being a synthesis of the interpretative black-and--white images MSS 4, 5, 6, 7

1 — Coniferous forests, 2 — Deciduous forests, 3 — Waters, 4 — Meadows, 5 — Farm land, 6 — Farm land belonging to large-commodity farms, 7 — Built up areas, 8 — Centre-of--town quarters, 9 — Water-course valleys hard to identify from satellite images, 10 — Railway lines, 11 — Plume of smoke.

(1) Differences observed in the phototone and texture of the image generally reflect relief of the region in agreement with the physico-geographical units and lead to some more general conclusions on land geology.

(2) Chances of inventorying water-courses in the region are very narrow and do not exceed, generally, twelve per cent. Much more satisfactory is, at the same time, the possibility of inventorying water reservoirs, lake and bigger rivers like the Vistula in the first place.

There is also the possibility of identifying areas with the shallow-situated (0 to 2 metres) first horizon of the underground waters.

(3) Satellite image under investigation have been found fully useful for identifying accurately acreage of such soils, as the black and grey meadow soils, hydromorphic soils and also podsols and rust-colured soils in some of the cases.

(4) Analysis of the texture of satellite material makes it possible to identify Quaternary relief areas varying in their age and degree of denudation.

(5) Satellite image is hundred per cent useful for inventorying woodland acreage and for identifying forests with the predominantly coniferous stand and forests with the dominant deciduous crop. Another outstanding feature is the possibility of a spatial assessment of the arable land in the large area and large-commodity farms. Rather unsatisfactory is the way in which such elements, as small settlements, meadows, swamps and barren land are exposed.

(6) Negligible is the percentage of identifiable linear elements, roads and railway lines in particular.

(7) Satellite images permit, on the other hand, the observation of such dynamic elements as the spreading of industrial smoke.

(8) Satellite images also prove to be the only valuable material in studying dynamics of some chosen elements of the land cover by comparing latest material with some previous and older cartographic sources.

To close our considerations it would be wise to add that quite deliberately use has been made in the analysis of the black-and-white satellite material as a material likely to find a possibly wide access to geographical laboratories which, as far as we are aware, are underinvested and badly equipped with analytical instruments and have, modestly saying, very small financial means at their disposal to get satellite material in colour.

REFERENCES

Galon, R. (ed.), "Nizina Mazowiecka" (The Mazovian Lowland) in: Galon, R., Klimaszewski M. (eds.), *Geomorfologia Polski* (Poland's Geomorphology), vol. 2, PMN, Warszawa 1972.

Kondracki, J., *Geografia Fizyczna Polski* (Poland's Physical Geography), PWN Warszawa 1978.

Gleby Polski (Poland's Soils Map) on the scale of 1 : 500 000, Committee for Soil Science and Agricultural Chemistry, Polish Academy of Sciences, Institute of Fertilization and Soil Science, Warszawa 1972.

Przeglądowa mapa geologiczna Polski 1 : 300 000, sheet Płock (Poland's Geological Survey Map) on the Scale of 1 : 300 000, sheet Płock, Rühle E. (ed.) 1948.

Przeglądowa mapa hydrogeologiczna Polski 1 : 300 000, sheet Płock (Poland's Hydrogeological Survey Map) on the scale of 1 : 300 000, sheet Płock, Kolago C. (ed.). Geological Institute, 1960.

Statistical Yearbook 1977, Central Statistical Office, Warszawa 1978.