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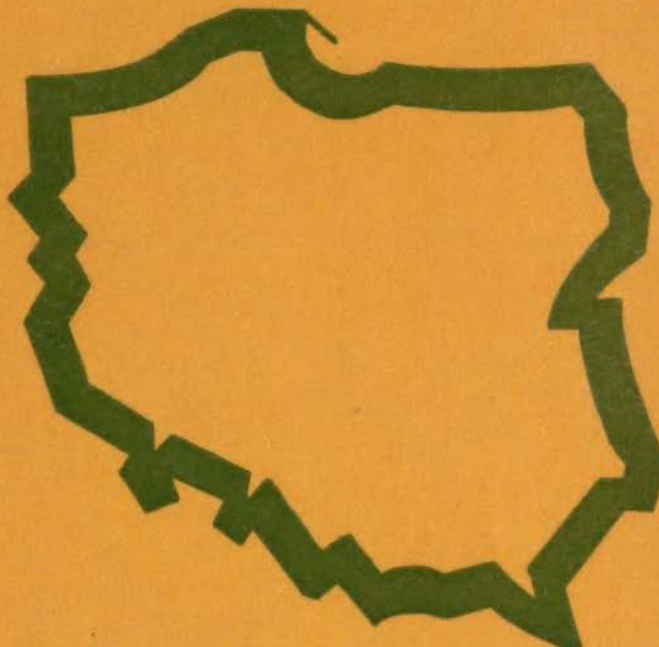
# GEOGRAPHIA POLONICA



48

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# GEOGRAPHIA POLONICA

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## PREFACE

There are doubtless multifarious close links between the geographical sciences and cartography. The two branches of science need each other and a development of one of them has an impact on the development of the other. This relation is also reflected in the fact that many centres of cartographic research and teaching are organizationally attached to faculties and institutes of geography. The links between cartography and geography are particularly evident in Poland, where six out of the eight cartographic departments and laboratories come under the organization of institutes of geography (of the Polish Academy of Sciences and the universities in Warsaw, Wrocław, Lublin, Gdańsk and Cracow), one is a part of the Faculty of Geodesy and Cartography of the Warsaw Technical University, and one belongs to the ministerial Institute of Geodesy and Cartography in Warsaw.

Cartography's important role for the geographical sciences is also due to the fact that the results of reserach of the latter are published in the form of thematic maps at different scales, both autonomous (often map series) and enclosed with books or papers. The content of those maps reflects the stage of development and current capacities of the branch of science concerned, whereas the graphic layout, notably the sign systems and choice of colours, are an outcome of the latest methodological studies in cartography, the cartographers collaborating in the editing and publication of the maps being responsible for their level and quality.

The present collection of papers presents some experiences and research of Polish geographers and cartographers in the field of the elaboration of thematic maps and some methodological problems. The authors represent, first of all, the Institute of Geography and Spatial Organization of the Polish Academy of Sciences (five papers), next, the Chair of Cartography of the Warsaw University Faculty of Geography and Regional Studies (three papers), the Cartographic Department of the Institute of Earth Sciences of the Maria Curie-Skłodowska University in Lublin (three papers) and cartographic departments at university institutes of geography in Wrocław, Gdańsk and Cracow (one each).

The papers presented in this volume fall into two basic groups, each of which has been subdivided into two smaller groups. The first nine papers present the latest. Polish research in selected areas of geographic thematic mapping, mainly those in which Polish geographers can boast rich traditions and valuable results in the form of map series. The group opens with a presentation of studies concerning natural environment — geomorphology (including the morphometry of ocean bottom), natural vegetation, and environment changes, successively. Socio-economic problems are ilustrated through a survey of Polish experiences in land use

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mapping, a dot land use map of Poland, a synthetic map of the types of agriculture in Europe, and an original attempt at presenting an isoplethic image of world population density.

The other group of articles concerns selected problems of cartographic representation. The first two deal with the representation of essential elements of map content: terrain relief and hydrography. The next three concern cartographic representation and transformation of statistical data. They provide a good illustration of the current interests and directions in the work of the two most active university cartographic centres: the one in Lublin, which launched experiments on the selection of basic unit areas thirty years ago, and the one in Warsaw, which is carrying on intensive investigation into the construction and transformation of choropleth maps.

Diverse fundamental problems of thematic cartography — theoretical, methodological and technical are the main items on the agenda of the 11th International Cartographic Conference in Warsaw (summer 1982). The purpose of such a selection of problems on the agenda was to provide for an exchange of experiences and a presentation of the latest achievements in this rapidly developing branch of cartography. We hope that the present selection of papers, an illustration of the contribution of Polish geographers and cartographers in this field, will also serve this purpose.

JERZY OSTROWSKI

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# THE 1:500 000 GEOMORPHOLOGICAL MAP OF POLAND

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The 1:500 000 Geomorphological Map of Poland, the purpose of which is to reconstruct the relief evolution in general by taking morphostructures as well as genetic relief types fully into account, synthesizes up-to-date work on the relief of Poland. An additional aim of publishing this map by the Institute of Geography and Spatial Organization, Polish Academy of Sciences, was to put forward a geomorphological division of the country. The map also places in focus the lacunae of geomorphological research which need further detailed studies. This map was constructed in the Cracow Department of Geomorphology and Hydrology of Mountains and Uplands, acting in co-operation with expersts from all major scientific centres in Poland (cf. legend for the map). The map was edited by Prof. L. Starkel, with the assistance of Dr. S. Gilewska and Mrs. M. Klimkowa who also has handdrawn all sheets. Dr. K. Trafas and his collaborators of the Polish Society of Earth Sciences have taken part in the preparation of the final cartographic edition of the map which was printed at the Wojskowe Zakłady Kartograficzne, Warsaw. Map data relate to 1968.

## HISTORY OF THE MAP

The first map legends were proposed by Klimaszewski (1946), Galon and Roszkówna (1953), and by Kondracki (1963). Since the latter legend has contained only genetic and chronologic data, there was a need for a new map legend. Valuable suggestions on its basic principles have been made by Klimaszewski and carefully considered by Starkel who undertook the work on a completely new legend (1967, 1974).

For the purpose of giving as complete an account as was possible of the landforms that occur in Poland, the map was compiled by persons who were active in the exploration of the individual regions. Since field observations were frequently lacking where they would be most useful, e.g. in Southern Poland, various maps, handdrawn and published, were used, especially the 1:300 000 *Geological Map of Poland*, all types of detailed geological maps, as well as the general geomorphological maps and the *Detailed Geomorphological Map of Poland* covering some 25 per cent of the country. The names of compilers and authors are given on each sheet.

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## THE CONTENT OF THE MAP

Landforms displayed on the map are divided into two major groups:

I. Principal neotectonic landforms repeatedly uplifted in Neogene and Quaternary times — mountains and uplands (=plateaux and hills) of erosional-denudational relief. This group contains

A. Crystalline massifs and planated mountains of old folding produced by uplift along fault-lines

B. Crystalline massifs and young fold mountains produced by intense uplift along tectonic lines

C. Young fold-(flysch) mountains folded in post-Paleogene times

D. Horizontal and subhorizontal structures composed of Mesozoic and Neogene sedimentary rocks.

II. Principal neotectonic landforms repeatedly depressed in Neogene and Quaternary times (lowland areas and basins), areas of sedimentation, for the most part showing accumulational features.

The above mentioned morphostructures comprise three major morphographic types, namely mountains, uplands (=*Hügelland*) and lowland areas. In the mountains and uplands containing remnants of old surfaces of planation variation in height reflects both the vertical relief arrangement (morphometry) and the sequence of events (relief evolution — morphochronology). Overprinted on the morphostructures are the genetic relief types including large landforms (mountain blocks and ridges, plateaux etc.) and landform elements, i.e. the small endo- and exogenic landforms which are grouped by origin.

## THE GRAPHIC REPRESENTATION

The above concept is expressed in the following way: The basic colours (brown, reddish violet and orange) indicate the major structures. Shades of brown, reddish violet and orange have been used to distinguish between the different major morphographic types and their height range. Three shades of green are applied to landform complexes, irrespective of their height, belonging to the three successive continental glaciations of Poland. Such type of representation required a high standard of reproduction in order to achieve the proper grading of the background colours, but this has been shown not to be the case. For that reason the previously used colours (Starkel 1974) have been largely changed in print so that the map is less attractive now. Single symbols in different colours denote the characteristic small landforms of differing origin (dunes, eskers, kames etc.). Furthermore, compound symbols were used to depict the polygenetic nature of the transition area (Gilewska and Starkel 1971), where the relict morainic and outwash (sandur) plains are superimposed on the protruding substratum of varied relief. A complete list of the symbols just described, with the explanatory notes, is given as an Appendix.

This six-sheet map is printed in 22 colours on an incomplete contour background in umber, with rivers, lakes and sea shores in blue. The highways and named towns in black were added by the cartographic editor at the very end of the work, so that the map is marked with errors, for instance, in the Silesian Upland and in the lake districts.

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## THE GENERALIZATION

We are well aware that there are differences between the content of the invidual sheets, and even between the neighbouring regions. What should be clear is that this is a pioneer map, although a 1:500 000 *Geomorphological Map of Poland* by Kalniet and Karaszewska was published in 1972. However, the latter is rather a school room map. When compiling the map discussed it was found that little or no data were available for the characteristics of some areas, for instance, in Southern Poland. Consequently, such areas were studied only on geological and topographical maps, and it was hardly possible to give the exact origin of landforms and their ages. Thus, some information may be out-of-date now.

Many difficulties were apparent in both interpretation and cartographic representation of the same genetic relief types by persons working either in the lowland areas or in the mountains, i.e. in the outer parts of the old mountains and uplands, where the pre-glacial landforms gradually merge beneath the mantle of glacial and fluvioglacial deposits. In some cases the map content may vary in accuracy because of the various ways of showing the smallest features on the map. The details selected by the Editorial Committee are those which the field research has suggested to be the most important ones for reconstructing the relief evolution. Thus, the map of the lowland areas does not show the innumerable small morainic mounds which combined to form the broad end-morainic belts. In contrast, single tiny mounds that resulted from glacial depostion appear in the southern part of the Silesian Upland indicating the position of the Middle-Polish (Saale) ice-margin there. Similarly, it was impossible to represent true to scale the individual remnants of a planation surface. The map shows only the occurrence and extent of the various genetic relief types, together with the basic chronologic data.

## SOME SCIENTIFIC ASPECTS

The map shows the distinct west-east belt-like arrangement of the principal morphogenetic zones in Poland:

the southernmost zone of young mountains and sub-Carpathian basins,

the central zone of old mountains and uplands,

the old-glacial zone lying within the limit of the Middle-Polish glaciation (*Altmoränengebiet*),

the northernmost young-glacial zone falling entirely within the Vistulian glaciation (*Jungmoränenlandschaft*).

The map reveals the influence of both structure (lithology and tectonic setting) and differential neotectonic movements on the resulting landforms. Structural influences are most clearly seen in the mountains and uplands. In the Sudetes Mts., large-scale faulting accompanied by movements of uplift has producted the massive mountain blocks of differing height and the intermontane collapsed basins. In the flysch. Carpathians, lithology, i.e. the proportion of resistant sandstone to shale in the flysch series, and their tectonic setting has clearly guided the formation of the different relief types. In the west, compact sandstone massifs and isolated mountains with a capping of sandstone due to the dissection of low-angle thrusts sharply contrast with a typical ridge-and-valley topography in the east, where, the flysch has been tightly folded. The excava-

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tion of the strike vales along the weakest Paleozoic series outcrop has also produced the striking ridges of the Świętokrzyskie Mts. Similarly, in the Sillesia-Cracow Upland, cuestas and broad vales follow the geological strike of the subhorizontal inter-bedded limestone, dolomite, sandstone and shale of Mesozoic age. In contrast slightly inclined and flat-lying marl and limestone series of considerable thickness give rise to the vast plateaux and broad ridges of the Lublin Upland. In the Polish Lowland an excellent example of the influence exerted by the structure on the relief types is the present distribution of the major end-morainic belts. These reflect in their shapes the depressions and elevations in the substratum.

In addition, the map shows the vertical step-like arrangement of the different erosional-denudational relief types which frequently surround the great tectonic domes, thus reflecting the successive stages of development. A complex analysis of the mutual relation of various smaller landforms (especially of tectonic and denudational scarps, stream-valley patterns etc.), together with supplementary data on the type of both weathering residues and different allogenic sheets makes it possible to reconstruct the course of planation, dissection and subsequent destruction of the older surfaces of planation (cf. *Geomorfologia Polski* 1972, Baumgart-Kotarba et al. 1976).

Careful examination of the smaller morphostructures, ridges and terraces indicates the upheaval of both the Beskid Niski Mts. and the Beskid Sądecki Mts., and the revival of old tectonic lines in the Carpathians, and even in the sub-Carpathian Oświęcim Basin (e.g., the Brzeszcze horst, Czarnocki 1935). In the Sandomierz Basin the characterisitc sequence of landform complexes may suggest the outward shifting of the basin axis (Starkel 1975, Gilewska 1980). In the adjacent Nida Basin, lardform anallysis provides evidence of both uplift and downwarping (Gilewska in Klimaszewski et al. 1972; Starkel 1975; Łyczewska 1975). The role of descendant movements of uplift of the shallowly seated subsurface structures in the fashioning of the Polish Lowland is illustrated by the patterns and assemblages of both deposits and landforms, such as kames, spillway channels and fluvial terraces. On the northern fringe of the uplands, local Holocene peat accumulations (bog plains) reflect the current subsidence of subsurface grabens, for instance, at Opoczno and Kleszczów (Baraniecka 1975a).

The map also reveals the imprint of earlier continental glaciations upon the landforms inherited from the Tertiary, for instance, drainage divertions, epigenesis, the different degrees of exhumation of the cuestas, ridges, inselbergs etc. from beneath the mantle of allogenic sediments. Thus, the map shows the complex nature of the transition area which forms ap almost unbroken west-east belt extending through the northern part of the old mountains and uplands to the Polesie. In the Polish Lowland, the map illustrates the belt-like arangement of morainic plateaux comprising more or less distinct marginal features, and of extensive outwash plains and spillways which pass into systems of glacier margin valley trains (*Urstromtäler*). The map makes it possible to reconstruct hoth the rhythm and mode of delegaciation during successive phases and stages of the ice-retreat, as well as the phases of valley development, i.e. the former proglacial and extra-glacial drainage directions, and the degree of subsequent modification of the glacial relief by various processes.

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The different active natural landforms (dunes, cliffs, gullies etc.) displayed on the map, together with the different relief types (high mountains, limestone uplands, loess covered areas etc.) give both direct and indirect indications of the present-day morphogetic processes. Thus, it may be possible to analyse a further stage in evolution of those areas which are affected by mass movements, gully erosion, piping, wind activity etc. Areas heavily modified by man are not included on the map.

## COMPARISON WITH OTHER MAPS

A brief review of some medium-scale geomorphological maps shows that it is the problem of landform classification by both morphostructure and appearance, and their cartographic representation which is most controversial. These maps also give more or less information about the genesis, height and age of the major relief types. Apart from the morphogenetic maps (Ergenziger and Jannsen 1969), there are complex maps on which the principal landforms are classified in different ways: I. the major morphographic types (landscape units), which have been subdivided into smaller morphostructural (or structural) types (Badea et al. 1979; *Deutsche Landschaften*... 1974; Pécsi 1969, 1972), and II. the principal relief types of differing origin being overprinted in solid colours on the major morphostructures in dot and linear patterns (Demek et al. 1966; Stehlik 1965; Vaptsarow et al. 1973). However, the most elaborate map legend integrating various geological and geomorphological data into an overall geomorphological synthesis is that of the 1:2 000 000 geomorphological map of the Danubian countries by Pecsi (1978). On this map, the tectionic-destructional relief contains different major morphostructures which are subdivided into a wide variety of small structural types, morphographic types, each of them varying by lithology and height etc.

The present map can be regarded generally as coming within the second category of maps just mentioned This map differs makedly in character, however, for the various morphographic types are not complicated by the structural (tectonic setting) and lithological properties of both bedrock and caprock. The above information is provided only by the major morphostructures and by the small structure-controlled landforms, for instance, the different types of mountain ridges, cuestas and other scarps, karst features, loess mantle etc. (compare Appendix). The map also varies in detail showing both large landforms of differing age and landform elements of various genesis, for instance, the individual ridges and strike vales of the Eastern (flysch) Carpathians instead of the 'ridge-and -valley topography' in general (compare Demek et al. 1968). Unlike the map by Pécsi (1978), the present map shows only the relict, altered glacial and fluvioglacial landforms that now characterize the formerly glaciated zone of Southern Poland. Consequently, it is not possible to reconstruct with accuracy the successive stages of the Quaternary relief evolution in some nearly drift-free areas, for instance, in the Lublin-Wolhynian Uplands.

In conclusion, the present map from its scope of content might be regarded as falling within the regional maps, but its five criteria for landform classification appear to meet the requirements of the geomorphological maps on medium scales. Valuable though the detailed lithological information is from many points of view it is open to further discussion

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in areas that have suffered continental glaciation, because of the complex nature of both relief and bedrock/caprock lithology (compare Gilewska 1980, p. 252).

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# LEGEND
# FOR THE GEOMORPHOLOGICAL MAP OF POLAND
# 1 : 500 000

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## PRINCIPAL NEOTECTONIC LANDFORMS REPEATEDLY UPLIFTED DURING THE NEOGENE AND THE QUATERNARY

### Crystalline massifs and planated mountains of old folding produced by uplift along tectonic lines

| | |
|---|---|
| **violet brown:** | |
| dark | Highest blocks (over 1000 m a.s.l.) — summit areas and mountain-sides |
| middle+black pattern | Medium-high mountains *(Mittelgebirge)* with remnants of planation surfaces initiated during the Paleogene |
| middle | Low mountains with remnants of planation surfaces initiated during the Neogene |
| light | Foothills with remnants of lower planation surfaces initiated during the Neogene |
| **burnt sienna:** | |
| dark | Blocks of intermediate height (500 — 1000 m a.s.l.) — summit areas and mountain-sides |
| very dark | Resistant ridges and mountains, residual peaks |
| dark + black pattern | Mountains with remnants of higher planation surfaces initiated during the Tertiary |
| middle | Foothills with remnants of higher planation surfaces initiated during the Neogene |
| light | Foothills with remnants of lower planation surfaces initiated during the Neogene |
| light+green pattern | Low foothills concealed by deposits dating from the older continental glaciations |

Slightly upheaved or downthrown blocks (up to 500 m a.s.l.)

| | |
|---|---|
| **greyish brown:** | |
| dark | Resistant ridges and mountains, residual peaks |
| middle | Low mountains and high foothills with remnants of Paleogene planation surfaces |
| light | Low foothills and remnants of Tertiary planation surfaces |
| ight+greyish green pattern | Foothills concealed by Cracow (Elster) deposits |
| light + green pattern | Foothills concealed by Middle-Polish (Saale) deposits |

### Crystalline massifs and young fold mountains produced by uplift along tectonic lines

| | |
|---|---|
| reddish violet, dark | High mountains (over 1800 m a.s.l.) of alpine type |
| reddish violet, middle | Medium-high mountains (1300 — 1600 m a.s.l.) with remnants of planation surfaces initiated during the Neogene |

### Young fold (flysch) mountains — folded in post-Paleogene times

| | |
|---|---|
| **burnt umber:** | |
| very dark | Medium-high mountains de resistance of residual type (700 — 1700 m a.s.l., local relief of 400 — 800 m) |
| dark | Low mountains (600 — 1000 m a.s.l., local relief of 300 — 400 m) and high foothills with remnants of planation surfaces initiated during the Neogene |
| middle | Foothills of intermediate height with remnants of planation surfaces initiated during the Pliocene |
| light | Low foothills and high intermontane basin floors containing remnants of level surfaces |

### Horizontal and subhorizontal structures composed of Mesozoic and Neogene sedimentary rocks

Medium-high table mountains

| | |
|---|---|
| beige +black patterns | Higher table mountains initiated during the Paleogene (800 — 900 m a.s.l.) |
| | Lower table mountains initiated during the Neogene (600 — 700 m a.s.l.) |

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Highest uplands *(Hügelland)* with remnants of old planation surfaces

| | |
|---|---|
| orange | Higher plateaux (400 – 500 m a.s.l.) |
| light orange | Lower plateaux and broad ridges (up to 400 m a.s.l.) |

Uplands with remnants of planation surfaces (largely Pliocene in age)

| beige: | |
|---|---|
| very dark | Higher plateaux and broad ridges (up to 400 m a.s.l.) |
| dark | Lower plateaux and broad ridges |
| middle | Tableland with remnants of the Neogene structural surface |
| light | Upland divides and basin floors with remnants of levelled surfaces on the weakest rocks (up to 40 m in height) |

Plateaux and ridges concealed by Quaternary deposits (landforms generally reflect those of the bedrock beneath), with patches of

| | | |
|---|---|---|
| light beige + greyish green pattern | | Cracow (Elster) deposits |
| light beige +green pattern | —g— | Middle-Polish (Saale) deposits |

## PRINCIPAL NEOTECTONIC LANDFORMS (LOWLAND AREAS AND BASINS) REPEATEDLY DEPRESSED DURING THE NEOGENE AND QUATERNARY – AREAS OF SEDIMENTATION

### Divides on degraded Miocene rocks, concealed by

| | | |
|---|---|---|
| chrome yellow, pale + greyish green pattern | | Cracow (Elster) deposits |
| chrome yellow, pale +green pattern | —w— | Middle-Polish (Saale) deposits |
| chrome yellow, pale | | drift-free |

## GENETIC COMPLEXES OF SMALL ENDOGENIC LANDFORMS

### Tectonic landforms

Tectonic scarps

| | | |
|---|---|---|
| Prussian blue, deep | ▼▼▼▼▼ | less than 100 m in height |
| | ▼▼▼▼▼ | 100 – 250 m in height |
| | ▼▼▼▼▼ | more than 250 m in height |
| Prussian blue, deep | + | Areas clearly showing uplift tendencies |
| | — | Areas clearly showing tendencies towards subsidence |

### Volcanic landforms

| | |
|---|---|
| red | Relict volcanic cones |
| | Necks and dikes (peaks de resistance) |

## GENETIC COMPLEXES OF SMALL EXOGENIC LANDFORMS

### Denudational landforms

Mountain ridges

below 250 m, over 250 m in height; these contain:

| below 250 m | | over 250 m | |
|---|---|---|---|
| burnt umber | | black | resistant anticlinal ridges |
| | | | resistant synclinal ridges |



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burnt umber / black

- resistant monoclinal ridges (hogbacks)
- resistant monoclinal ridges (with one slope of cuesta type)
- other resistant ridges
- ridges not depending on structure
- crests

burnt umber / black

- residual peaks and peaks de resistance on the water divides
- isolated inselbergs
- passes

Denudational escarpments in the Carpathians below 250 m, over 250 m in height; these contain:

burnt umber / black

- escarpments following the front of nappes
- escarpments of cuesta type following the front of nappes
- other scarps and denudational breaks of slope

Denudational escarpments within the old mountain– and upland zone low high these contain:

Prussian blue line + umber teeth

- fault line scarps (obsequent, inversional)

burnt umber / burnt umber

- sandstone cuestas
- limestone and dolomite cuestas
- gypsum cuestas
- lava scarps
- other scarps and erosional-denudational breaks of slope (including those mantled with Quaternary deposits)
- Outliers and uponliers bearing limestone and dolomite caps
- Outliers and uponliers bearing sandstone caps
- Tors

green — Boulder fields *(Felsenmeer)*

red — Great landslides

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### Landforms due to fluvial erosion

Small valley floors filled with

| | | |
|---|---|---|
| light green fill | | Pleistocene sediments |
| light blue fill | | Holocene sediments |
| red | | Great V-shaped valleys (in the mountains) |
| red | | Ravins and gullies (in loess areas etc.) |

Water gaps (only in the mountains and uplands)

| | | |
|---|---|---|
| Prussian blue lines + red teeth | | antecedent |
| red | | epigenetic |
| red | | other gaps |
| red | | Wind gaps |
| red | | Erosional edges, more than 20 m in height |
| red | | Other important terrace edges (in less well known areas) |
| red | | Undermined slopes, river cliffs |
| dark blue | | River channels (= rivers) |
| red | | Great abandoned loops (cut-offs) |

### Landforms due to fluvial accumulation-depositional and erosional-denudational terrace plains (also in the *Urstromtäler*)

Pleistocene terrace plains dating from the

| | | |
|---|---|---|
| green earth: dark | *k* | Cracow (Elster) glaciation |
| green earth: middle | *s* | Middle-Polish (Saale) glaciation |
| green earth: light | *b* | Vistulian |
| green earth: very light | *p* | not subdivided |
| light blue | | Holocene floodplains and supra-floodplains |
| light green +green pattern | | Pleistocene alluvial fans (plus outwash fans in the Podhale) |
| light blue+ dark blue pattern | | Holocene alluvial fans |
| light blue+ dark blue pattern | | Holocene delta plains |
| light green +green pattern | | Plains due to accumulation by both fluvial and slope processes |

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**Landforms due to glacial and fluvioglacial erosion**

| | |
|---|---|
| crimson | Glacial cirques and troughs in the mountains |
| | Ice-contact slopes (scarps) dating from the |
| crimson | Middle-Polish (Saale) glaciation, altered |
| | Vistulian |
| | Subglacial channels (with lake) dating from the |
| crimson line + pale crimson fill | Middle-Polish glaciation (transformed) |
| | Vistulian |
| green | Marked edges of outwash (sandur) plains (in well know areas) |

**Landforms due to glacial and fluvioglacial accumulation, now degraded, occurring within the limit of the Cracow (Elster) glaciation**

| | |
|---|---|
| light greyish green + greyish green pattern | Plains due to periglacial denudation, resulting from the alteration of former glacial and fluvioglacial landforms |
| light greyish green + greyish green pattern | Relict mounds composed of morainic and fluvioglacial deposits |
| greyish green | Denudational scarps (superimposed on the background form) |

**Landforms due to glacial and fluvioglacial accumulation, now degraded, occurring within the limit of the Middle-Polish (Saale) glaciation**

| | |
|---|---|
| light green +green pattern | Undulating morainic plateaux |
| light green | Hilly marginal zone |
| | Morainic ridges and relict mounds in the marginal zone, formed by |
| Hoocker's green + crimson pattern | thrust (Odra stage) |
| Hooker's green | deposition (Odra stage) |
| emerald green + crimson pattern | thrust (Warta stage) |
| emerald green | deposition (Warta stage) |
| light green +green patterns | Degraded morainic plateaux and outwash (sandur) plains – in less well known areas |
| | Degraded outwash plains and extensive kame terraces |
| | Degraded outwash fans |
| | Landforms due to melting out of buried ice blocks |
| light green +green patterns | single small kettles and groups of small kettles |
| | single small thaw basins containing secondary forms |
| | large thaw basins containing secondary forms |

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Kames

| | |
|---|---|
| light green +green patterns | single small kames and kame terraces |
| | groups of small kames and great kame terraces |
| | single kame plateaux |
| | Eskers |

Denudational landforms resulting from the alteration of glacial and fluvioglacial depositional landforms

| | |
|---|---|
| light green + green patterns | denudational scarps |
| | long slopes of morainic plateaux, large morainic ridges etc. |
| | plains of pediment type produced by periglacial denudation |

## Landforms due to glacial and fluvioglacial accumulation dating from the Vistulian

| | |
|---|---|
| olive green | Depositional moraines left by valley glaciers |
| light olive green + olive green pattern | Undulating morainic plateaux |
| light olive green | Flat morainic plateaux |
| middle olive green | Hilly marginal zone |

Morainic ridges in the marginal zone, formed by

| | |
|---|---|
| dark olive green + crimson pattern | thrust |
| dark olive green | deposition |

Drumlins

| | |
|---|---|
| light olive green +olive green patterns | groups of drumlins |
| | drumlinoid surfaces |
| | Outwash (sandur) plains |
| | Outwash fans |

Landforms due to melting out of buried ice blocks

| | |
|---|---|
| light olive green +olive green pattern | single small kettles and groups of small kettles |
| | single small thaw basins |
| | large thaw basins |

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Kames

| | |
|---|---|
| light olive green +olive green patterns | single small kames and kame terraces |
| | groups of small kames and great kame terraces |
| | Eskers |

**Karst landforms, Quaternary in age**

| | |
|---|---|
| red | Karst gorges |

Sinkholes developing in

| | |
|---|---|
| red | limestone |
| | soft chalk |
| | gypsum |
| | Karst lake basins |
| | Caves |

**Suffosional (piping) landforms, Holocene in age**

| | |
|---|---|
| red | Groups of suffosional pits, valleys etc. |

**Aeolian landforms, Late Glacial and Holocene in age**

Areas of deflation

| | |
|---|---|
| red | active |
| burnt umber | inactive |

Groups of dunes

| | |
|---|---|
| red | active |
| burnt umber | stabilized |

Single parabolic and other dunes

| | |
|---|---|
| red | active |
| burnt umber | stabilized |
| zine yellow, pale | Wind-blown areas |
| orange | Older relief bearing a thick loess mantle with a set of characteristic small forms |

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**Organogenetic landforms, Holocene in age**

| | |
|---|---|
| burnt umber | Bog plains |
| light blue+ umber pattern | Compound plains due to plant accumulation on sea- and lake shores and in the river valleys |

**Limnic landforms, Quaternary in age**

| | |
|---|---|
| Prussian blue, deep | Lake basins (= water surface) |
| light Prussian blue +blue pattern | Plains due to lake water deposition |
| light green earth +green pattern | Plains — infilled ice dammed lakes |

**Landforms due to marine abrasion, Holocene in age**

Cliffs

| | |
|---|---|
| red | now undercut |
| | inactive |

**Landforms due to marine deposition**

| | |
|---|---|
| Prussion blue, deep | Beach ridges |
| | Spits with well developed beaches |
| | Tidal deltas |

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# APPRAISAL OF USEFULNESS OF MORPHOMETRIC INDICES EMPLOYED IN CHARACTERISTICS OF OCEAN BOTTOM CONFIGURATION

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As there is an evident shortage of precise data on natural environment, including the terrain configuration, when researches undertake any attempt at a systematization of relief features, they employ genetic or morphological criteria and very seldom refer to the most tangible, external variables. The main problem is the amount of labour any morphometric methods demand. When some years ago the author of the present paper launched this study, her goal was to find such indices of relief which would eliminate the task of repeated measurements of individual morphometric values on the map. The easiest way would be to reduce the problem to the transformation of a traditional map into a numerical map. In practice, individual isohypses would have to be replaced by a set of points on this isohypse of known geographical coordinates. Such a map could easily be recorded in the memory of a computer. Basing on this record or the image of the distribution of figures, one would be able to compute every morphometric index which can normally be calculated from the map. It would also provide a perfect groundwork for a classification of features according to morphometric and cartometric criteria. Naturally, apart from such a deailed record, one can employ other methods, e.g. adopt only randomly selected points (overlay a grid of $x$-side squares on the map and read the coordinates and values of only the points of intersection of the lines of the grid) or characteristic points of the given form (e.g. points located on crest and valley lines). Many such attempts have been designed, but none of those methods has been employed in practice. The investigation of relief with the use of mathematical models is still at the stage of experiments and theories. One of the reasons seems to be the lack of adequate comparisons of results obtained in this way and the findings related to the same area and matter obtained with the use of traditional methods.

In order to refute the possible charges that the results obtained by means of certain simplified mathematical assumptions were not juxtaposed with practice. or, rather, with nature, we resolved to begin the study with the elaboration of a set of morphometric maps by means of traditional methods, i.e. to compute repeatedly the values of indices for all of the selected area and, basing on them, attempt to discern some features.

The present study is an attempt at presenting relative altitudes and, consequently, the degree of ocean bottom dissection on the basis of data derived from a map. As the growing number of relevant morphological

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studies indicate, ocean bottom configuration not only exerts a direct influence on the hydrological situation, but also provides a valuable direction in the preliminary investigation of the origin of different areas.[1]

In order to examine the usefulness of different methods for the solving of morphogenetic and morphological problems of ocean areas, all the calculations were derived from a uniform hypsobathymetric presentation of the earth's surface provided by the 1:10 000 000 map *Relief of the Earth's Surface.*[2] The fact that the map was elaborated in Lambert's equal-area azimuthal projection greatly facilitated the division of the area into basic unit areas. Besides, the map may be used in this type of cartographic studies due to the fact that 500 m equal distance between isohypses and isobaths is preserved nearly troughout the map.[3]

However, as the scale is relatively small, in detailed studies this map had to be complemented with data derived from larger-scale maps,[4] which, unfortunately, do not have the merits of the map.

*Relief of the Earth's Surface.* In order to collect the greatest possible number of data providing for a relatively objective and versatile image, employed were methods based on reference fields, which supply mean values, as well as measurements along selected sections (profiles). In some cases distances between isohypses and the distances separating them from the shore line were analysed, i.e. the widths of individual depth levels vere compared. Each of those mefhods conceals some measure of generalization or subjective treatment, which, depending on the scale of the map, may to a greater or smaller degree influence the final result.

For purely practical reasons (the chance to refer to the shore line — a generally accepted boundary between two environments), most of the research was conducted in the zone no more than 400 km beyond the shore line. Only two maps were elaborated for the area of the whole earth; a map of relative altitudes and a map of summit surface. Also the vast majority of profiles were made for all of the continental slope.

In the case of maps covering all of the earth's surface, the division into unit areas was borrowed from F. Uhorczak's manuscript maps elaborated at the Cartographic Department of The Maria Curie-Skłodowska University in Lublin. Uhorczak used fields of 1 milion km² in area, dividing the earth's surface into 510 such fields (255 on each hemisphere). The fields were obtained by way of dividing parallel zones into spherical trapezia. A shift of trapezia in relation to each other within the zones allows interpolation based on sides of triangles.

In the cases when the final result was referred to the shore line, we used our own division into unit areas, the only commons feature of which

[1] See A.V. Ilin, *Geomorfologia dna Atlancticheskogo Okeana*, Moskva 1976, Nauka.

[2] M. Pelczar, *Rzeźba skorupy ziemskiej w izohipsach i izobatach* (Relief of the Earth's surface — isohypses and isobaths). Gdańsk–Lublin 1977. The map at the scale of 1:10 000 00 consists of the Northern Hemisphere and the Southern Hemisphere. It is divided into 14 sheets, the basic sheet lines are along 90°E and 90°W meridians, but the polar regions are preserved in full. The geographical graticule lines are plotted at 10° distances.

[3] With the exception of small areas in high mountains where for technical reasons it was not possible to delineate vertical intervals smaller than 1000 m.

[4] The source material for ocean bottom relief were Soviet general maps elaborated on the basis of data collected during oceanographic expeditions in the years 1956–1969 published by GUGK (Moskva 1971), and navigation charts published by various hydrographic institutes.

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was their size. Unfortunately, due to the assumption that the unit areas were to be based on zones mapped by equidistant lines 100, 200, 300 and 400 km from the shore line, the requirement of comparability of shape had to be dispensed with. Nevertheless, all the fields 10 000 km² in area are approximations of trapezia.

Calculated in reference to those fields were:

1. Relative depth. This value may be considered fundamental for a preliminary examination of the degree of differentiation of relief in the area. Partch (1911), de Marton (1941) and others assumed altitude rifferences to be indicators of relief gradient (German *Reliefenergie*).

Isarithmic maps elaborated on the basis of interpolation of values assigned to geometrical centres of unit areas provided a rather complex image of relative depths, which, however, converged with the complex bottom configuration (Fig. 1).[5] Another attempt at a graphic presentation was the replacement of an isarithmic map by a choropleth map (Fig. 2).

The value 500 m was adopted both in the interpolation of isarithms and in choropleth map intervals.

2. Mean slope of the area, according to Finsterwalder's formula:

$$\tan\alpha = \frac{h}{P} l + l_2 + \dots + = \frac{hl}{P}$$

$h$ — value of bathymetric interval (500 m), $P$ — size of unit area (10 000 km²), $l$ — total lenght of isobaths within the field.

This image makes it possible to use numerical values in every arbitrarily selected point, which is essential for computers. Besides, it illustrates the so-called 'flatness' of the bottom. As is exemplified by the Antarctica shores (Fig. 3), this image does not always perfectly converge with the isobathic image.

3. The index of the so-called 'bottom dissection' may be calculated from, among others, the ratio of the real length of isobaths and their theoretical lenght, i.e. the length of a straight line. Many researchers claim that this index also defines 'relative relief' (*Reliefenergie*). In this study, the index was used first of all to prove that those two indices may only be considered equivalent when dealing with very small areas with very small contour intervals. Even when a 100 km zone is considered, the differentiation is so great that any synthesis is virtually unfeasible. In the case of the presented fragment of the shore it ranges from 1.0 to 1.8, and there is no correlation with relative depths. The index of variability of isobaths, or as we generally call it bottom dissection, may and should complement the calculation of relative depth, but it can never replace it (Fig. 1 and 4). It is contingent on the map scale to an even greater degree than other indices.

The use of unit areas as the basis for any type of calculations in morphometric studies has unquestionable advantages. This image eliminates to a greatest possible degree subjective evaluation and the error which is inherent in every single measurement. As it has frequently been emphasized, it is easy to transform this type of a picture to numerical map or a record in the memory of a computer. However, unit areas are inadequate when a problem is to be analysed in great detail or from many angles in order to grasp the essential features (e.g. classification of shores).

[5] Figures 1–4 are enclosed separately under the back cover.

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When one attempts to compute mean values, i.e. 'slur' the calculated results, what is obtained bears no resemblance to nature.

In such cases profiles turn out to be irreplaceable. Although it is a typical cartometric method usually employed as a graphic representation of relations of depth or altitude, it was used in the present study as the basis for the calculation of the relative share of particular depths and the angle of parts of the continental slope.[6]

The lines of profiles were plotted perpendicular to the shore line at 100 km intervals, and in particularly characteristic points the intervals were reduced to 25 km.

A set of profiles was also used to compute the value of mean depth, which has traditionally been determined by the labour-consuming procedure of plotting the bathygraphic curve.

The computations were carried out for the Indian Ocean. Although it is the smallest of oceans, it is a unit big enough to be treated as representative. Another reason for its selection was that its shape approximates to a circle.

The difference between mean depth obtained with the use of the traditional method (bathygraphic curve) and the value derived from profiles never exceeded 1.5 per cent. In larger areas (the whole ocean) it equalled 0.9 per cent. To obtain that result, profiles were plotted at 100 km intervals (i.e. 1 cm at the scale of 1:10 000 000).

Yet another way of a numerical approach to under-water relief is to define distances between individual isobaths. In order to do that, one must make a table of values appropriately divided into intervals. The result is a set of indices not only of a taxonomical character. For instance, distance:

0 to 10 km — index 1 — angle of slope 2°57′ — ~ 90°
10.1 to 50 km — index 2 — angle of slope 0°45′ — ~ 2°56′
50.1 to 100 km — index 3 — angle of slope 0°34′ ~ 0°44′
over 100 km — index 4 — angle of slope up to ~ 0°33′

When analysing the usefulness of different methods for a characterization of ocean bottom, a brief comment is due to the image obtained after the computation of individual indices.

The distribution of maximum local relief determined by way of calculating the differences between the highest and lowest points within the reference fields provides some idea of the degree of relief differentiation of the area.

Owing to the fact that the computations were performed for vast areas on the map of the whole earth, the boundaries of many powerful features such as the Mid-Atlantic Ridge were less emphasized, whereas the ranges of main geological structures and essential morphological units (the so-called megafeatures) were very conspicuous. The same index calculated for zones extending along the shore line in much smaller unit areas — 10 000 km was adopted as the basis for distinguishing different types of ocean bottom relief of the upper part of the continental slope.

It turned out that when differences in depths are adopted as the basis and are complemented with results obtained from a computation of the

[6] The total of over 4000 profiles perpendicular to the shore line were elaborated for the zone of the continental slope. A detailed analysis of them was presented in the author's paper: *Wyznaczanie granicy szelfu w oparciu o kryteria morfometryczne* (Determination of shelf boundary one the basis of morphometric criteria). Materials of the 8th International Cartographic Conference, Moskva 1976.

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index of isobath stretch it is possible to distinguish five clear types of under-water relief which markedly differ from each other.[7]

The elaborated profiles confirmed this distinction. As an analysis of the shape of the profile and the angle of slope in different parts of its showed, there is a clear convergence (reaching 0.78) between the picture of the section obtained and the types of relief features distinguished by means of very laborious morphometric calculations.

As it was mentioned earlier, a map of the so-called summit surface was elaborated on the same 1 000 000 km² fields as the map of local relief. The map may be the basis for a physical characterization of the earth's surface treated as continuous, smooth area. Naturally, this picture differs fundamentally from the map of local relief. Areas with maximum density of isarithms, which represent the most abrupt changes of altitude, are situated parallel to the shore line of continents, and in some cases, where there are no vast highlands (e.g. in Argentina), parallel to mountain range massifs. This image reflected better than the image of relative altitudes the general traits of some areas, such as the flatness of the Indian Ocean bottom parts lying at great depths or of the greatly elevated parts of Central Africa.

However, most of the indices mentioned here and those which might also be calculated directly from the map (e.g. mean slope of individual bathymetric levels,[8]—which is of essential importance when investigating the accumulation of bottom depositis, or the density of the valley system in the shelf area or canyons in the continental slope) are contingent, as it has repeatedly been stressed, on the size of the unit area. When on the other hand, the unit areas of divergent sizes are used, the results may be accused of relativity, which should be avoided especially now that automation is progressing.

Having elaborated a whole set of morphometric maps, the author of the study reverted to profiles as the only truly direct presentation of depths which also makes possible the computation of the angle of slope and mean depth, i.e. all the data indispensable for a characterization of relief. The study was not limited to profiles treated as sections derived from the map; examined were also profiles plotted on the basis of an interpretation of echograms.

It remains to be seen whether it is possible to attempt a classification of ocean bottom features on the basis of profiles. The available data indicate that it is possible, but a definite answer requires more detailed survery material than is now at the author's disposal.

The main problem is to obtain a sufficiently large set of echograms made along the same lines as for plotting profiles from the map. When this problem is solved, one might obtain any number of data relative to the configuration of ocean bottoms, an important component of natural environment treated as a system. It will also be possible to conduct morphometric studies without the use of a hathymetric map, which always provides a generalized image, and to derive all data from direct measurements.

[7] They are: 1) poorly dissected flat shelf areas, 2) strongly dissected flat shelf areas, 3) poorly dissected fragments of the continental slope, 4) strongly dissected fragments of the continental slope, 5) strongly varied bottom zone with many under-water elevations.

[8] The bathygraphoid constructed by F. Uhorczak may be taken as a graphical illustration of this index.

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# GENERAL MAP OF POTENTIAL NATURAL VEGETATION OF POLAND

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The editing of the map of potential natural vegetation of Poland has been under way since 1965. Tüxen's (1956) idea of a map of today's potential natural vegetation was accepted as its theoretical basis. Professor Władysław Matuszkiewicz is the initiator of this work in Poland. Work on the map is being done by teams of authors assembled in the following centres: Warsaw, Poznań, Toruń, Szczecin, Łódź, Cracow, Katowice and Białowieża.

Field work has been almost completed — there are still two sheets of maps at the scale of 1:100 000 to be mapped in 1981. There is also laborious field work left on correcting some sheets and the coordination of edge matching. In certain most controversial cases the coordinating team may consider it necessary to re-map disputable areas.

An ample legend of 68 symbols has been designed for the potential natural vegetation of Poland. The legend is graded:

— Families of colours provide information to which combination the given separation belongs (e.g. green colours mean Carpinion Alliance).

— The Association which is the basic legend unit, has been marked off with one colour. 45 such units have been distinguished.

— Colour tones show regional varieties and altitude forms within groups. Regional varieties occur in such plant communities as: alder carr, beech, pine forest, spruce forest, and a forest with a large share of hornbeam and oak; whereas altitude forms (piedmont and subalpine) occur in hornbeam and oak forest and beech forest.

— One of the tropistic aspects, namely generosity form, has been mapped in respect to the most frequently occurring group in Poland (hornbeam and oak forest). It is marked with hachures on the map.

— The legend contains one symbol which does not fit in the described hierarchical system of the areas where vegetation has been completely destroyed and the site transformed to the degree precluding possibilities to forsee the course of natural succession. Such a separation has been called industrioclimax. It is marked with solid black.

— The separated plant communities are marked mainly with the use of the surface method. In the case of rare communities occurring in small areas the symbol method has been used.

— The multi-colour map of potential natural vegetation of Poland at the scale 1:300 000 is to be printed in 11 sheets forming an atlas with a commentary. Situational backround worked out at the Institute of Geography and Spatial Organization of the Polish Academy of Sciences will be used. Six such sheets have been completely designed (see Fig. 1).

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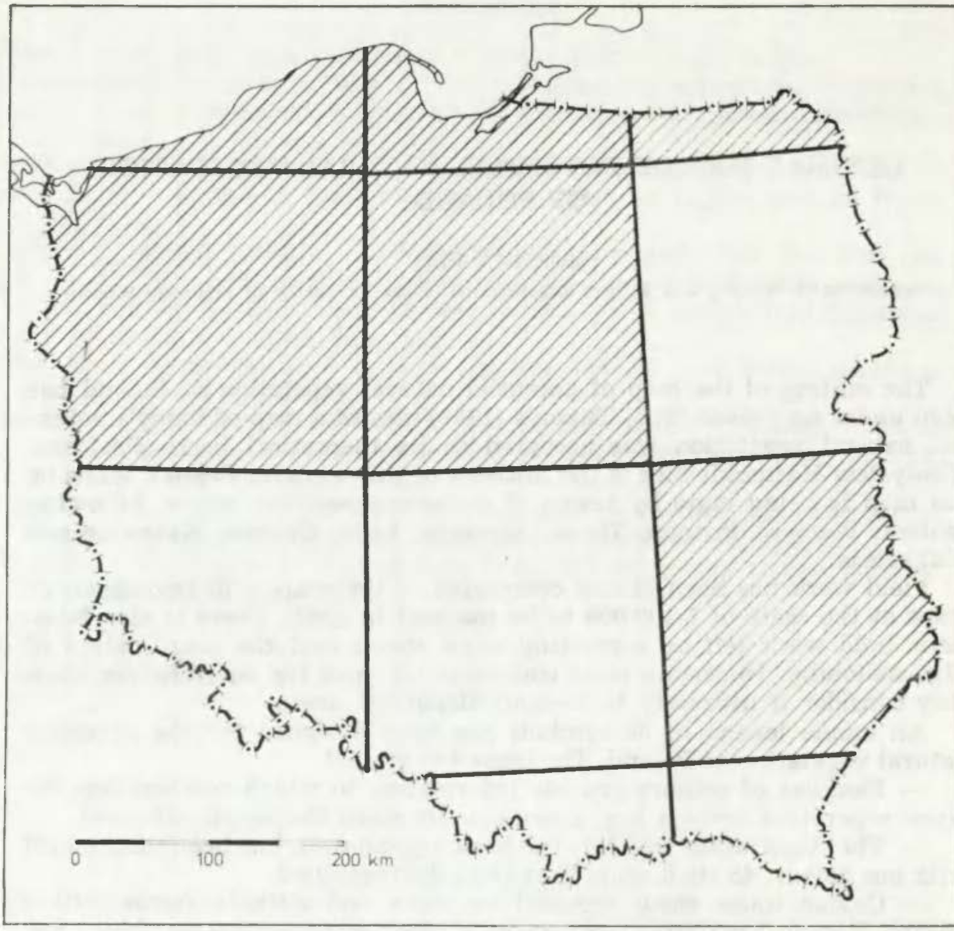


Fig. 1. Scheme of division into sheets and stage of progress in editorial work on the General Map of Potential Natural Vegetation of Poland

Apart from the atlas version of the map, a number of regional sheets have been designed and published. Since they were published, as annexes to different publications they are difficult to assemble. Figure 2 illustrates maps published so far and provide information about the way they were published and the scale of the map. The area covered by the published sheets constitutes a remarkable part of the area of Poland. Maps are not distributed evenly and a number of them have an overlapping coverage.

A considerable number of the maps have been published in black and white. They are the following:

1. Today's Potential Natural Vegetation of the Hights of Gorowo and the Orneta Plain, 1:200 000 by Faliński (1966).
2. Potential Natural Vegation of the Warsaw Basin, 1:300 000 by W. Matuszkiewicz (1966).

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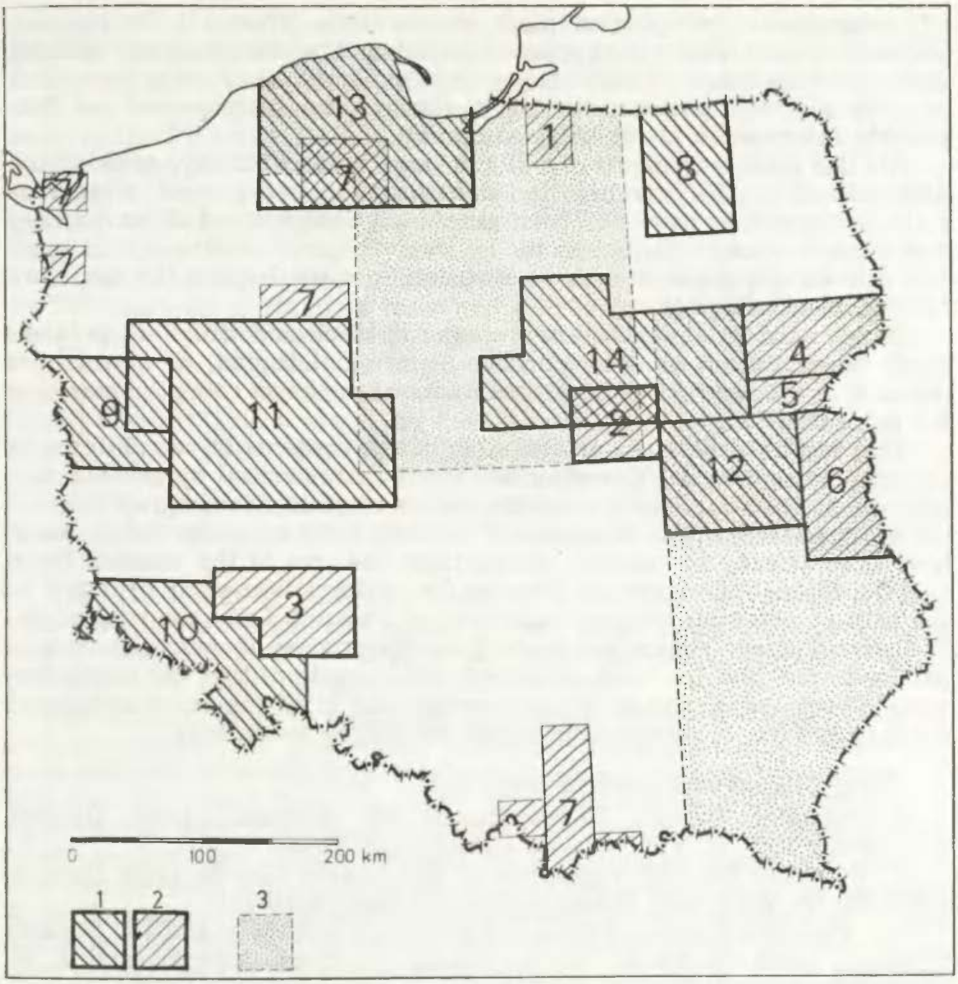


Fig. 2. Published maps of potential natural vegetation
1 — multi-colour maps at general scales, 2 — black and white maps at general scales, 3 — maps at the scale of 1 : 1 000 000

3. Potential Natural Vegetation of the Silesian Lowland, 1:300 000 by W. Matuszkiewicz (1967).
4. Potential Natural Vegetation of the Bielsk High Plain 1:300 000 by Falinski (1968a).
5. Potential Natural Vegetation of the Drohiczyn High Plain 1:200 000 by Falinski (1968b).
6. Potential Natural Vegetation of the Podlasian Polesye 1:300 000 by Solińska-Górnicka, Fazlejew and Chojnacki (1978).
7. Seven maps of potential natural vegetation 1:300 000 annexed to the Guide to the Polish-International Excursion (1978).

The legend to the black and white version of the map of potential natural vegetation has been graphically designed by Neli Olszewska. It is consistent. Symbols have been grouped logically into families according

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to syntaxonomic grouping of plant communities. Thus, all the riparian lowlands are marked with vertical hachuring, line thickness and spacing differentiating concrete plant communities; coniferous forests are marked with a dotted pattern, thickness, density and arrangement of dots provide information about the community.

All the graphic symbols are of the same optical quality, none of the designations has been transferred onto the map background. Even rare plant communities have not been graphically emphasized although they make the landscape characteristic by their frequent occurrence in small areas. In consequence of such a construction of the legend, the maps are not sufficiently legible.

Maps of potential vegetation prepared in black and white are published in two variants: older maps have an original legend, in newer ones (items 6, 7) the legend has been photoreduced to one third as the maps are far more detailed.

The degree of detailed presentation of the contents is not uniform on the sheets in question. The older maps are characterized by greater simplification. The simplification results not so much from cartographic generalization as from a less detailed and accurate field mapping. (Some sheets have been already re-mapped, among them the area of the Warsaw Basin and the Silesian Lowland, to provide for uniform treatment of detail on the map of potential natural vegetation of Poland). Only the map of the Podlasian Polesye region has undergone the process of generalization, in particular the line has been smoothed, but in spite of this the map's drawing is very dense. The situational background in all the above mentioned maps is meagre. It covers main rivers anl larger towns only.

The published multi-colour maps are:

8. Potential Natural Vegetation of the Mazurian Lake District, 1:200 000, 1:300 000, 1:500 000 by Faliński (1971).
9. Potential Natural Vegetation of the Lubusz (Lebus) Lake District, 1:300 000 by Wojterski, Leszczyńska and Piaszyk (1971).
10. Potential Natural Vegetation of the Sudetes Mts, and the Sudetes Foreland, 1:300 000 by W. Matuszkiewicz, A. Matuszkiewicz, and J. M. Matuszkiewicz (1978).
11. Potential Natural Vegetation of Central Great Poland, 1:300 000 by T. Wojterski, H. Wojterska, and M. Wojterska (1978).
12. Potential Natural Vegetation of the Siedlce High Plain, 1:300 000 by J.M. Matuszkiewicz, Kozłowska, and Chojnacki (1980).
13. Potential Natural Vegetation of the Gdańsk Pomerania, 1:200 000 by T. Wojterski, H. Wojterska, and M. Wojterska (1981).
14. Potential Plant Communities of Northern Mazovia, 1:300 000 by J.M. Matuszkiewicz (1981).

The legend to the colour version of the map has been prepared by Faliński, A.J. Matuszkiewicz, and J. Plit. It is being continuously modified and improved. Although this makes reading of this series of maps more difficult but this atlas version of potential natural vegetation of Poland is expected to be graphically designed in the best possible manner. The general idea of the legend has not changed: hormbeam and oak forests are green, beech-dark green, pine coniferous forests — yellow, mixed coniferous forets — brown, riparian lowlands — blue.

Many suggestions have been made for the colouristic solutions of plant

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communities consisting of beech groups and mixed coniferous forests. The solution adopted on the map of the Gdańsk Pomerania seems to be the best of them all. Acid beech occurring on lowlands (*Luzulo pilosae-Fagetum*) has been marked with light celadon. This community occurs in large areas in the Pomerania. The light colour allows it to be read as the background of the map. This is of particular importance because of great changeability of vegetation in this region. Wojterski's marking of the acidophil oak and red beech forest (*Fago-Quercetum*) with strong celadon is controversial. This plant community belongs to the group of mixed coniferous forests and not to red beech forests. The author has clearly been guided by the make-up of stand of trees and not by the taxonomic category of the community. One can hardly agree with T. Wojterski as to the marking of ash-elm riparian lowlands (*Ficario-Ulmetum*) with dark green (green tones mean variations and generosity forms of hornbeam and oak forest) and not with a blue tone (meaning riparian lowlands). This is habitually done on the map of Central Great Poland and the Gdańsk Pomerania. As a result, characteristic landscapes of great river valleys and the Vistula Delta (Żuławy) are not sufficiently separated from the surrounding hornbeam and oak forests. Moreover, the legend consistency has been broken.

Tropistic series of hornbeam and oak forests have been marked with separate colours (darker and lighter green), which is inconsistent with the earlier conventions of the legend. It seems that an irrelevant, internal difference has been raised in rank in this way.

The maps have been published in pastel light colours. Full (solid) colours are rarely used. Difficulties in distinguishing colours and identifying some separations result from this idea of graphic design. It is difficult to tell *Luzulo pilosae-Fagetum* from *Fago-Quercetum* or *Calamagrostio-Quercetum* from *Pino-Quercetum* in dry form on the map of Central Great Poland. The difference between piedmont hornbeam and oak forest and beech is too small on the map of the Sudetes Mts. and the Sudetes Foreland, and internal division of beech is too inconspicuous. Unexpectedly, changeability of the varieties of hornbeam and oak forests has been exaggerated. As a result of the graphic convention the Sudetes treshold has been emphasized whereas multi-stratum mountain vegetation has been blurred. The division of ranges depending on the type of soil so characteristic of the Sudetes Mts. (generous — poor, acid — alkaline) is not sufficiently legible.

Considering the fact that the legend of the map of potential natural vegetation of Poland consists of 68 symbols, it will be necessary to give up the idea of light pastel colouring. In the atlas version, colours must stand in one-to-one correspondence and so the differences among the colours must be greater. Moreover, each separation will be marked with a numerical symbol similarly as on the map of the Gdańsk Pomerania.

The degree of detailed presentation on those sheets is not uniform. T. Wojterski's maps feature a much greater generalization of shapes and simplified, smoothed lines. It considerably decreases the information about structural differences among regions. The maps by J.M. and W. Matuszkiewicz and Faliński show a considerably minor generalization. Separations are more segmented, lines less smoothed and pains have been taken to emphasize even minor regional differences. (It can be easily observed

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on the map of the Sudetes Mts. and the Sudetes Foreland or Northern Mazovia).

Apart from a quantitative generalization, a qualitative generalization has been carried out. T. Wojterski consistently generalizes the intermediate stirp (mixed coniferous forest) between coniferous forest and hornbeam and oak forest or coniferous forest and generous beech. Sometimes two intermediate links are omitted and generous hornbeam and oak forest and coniferous pine forest are in an immediate contact. Other authors prefer exaggerating the intermediate strip to omitting it altogether. Such junctions occur in exceptional cases but then there must be important reasons for it (e.g. high slopes, change of geological substratum, etc.).

The situational background of the colour maps of potential vegetation is not uniform. It is inconspicuous on the map of the Mazurian Lake District. Lakes, rivers and bigger towns have been marked. All the other maps show a denser network of settlements, transportation routes (roads and railways) have also been warked.

Geobotanic contents has been supplemented on a number of sheets with Walter's climatic diagrams, location hypsometric map and occasionally with geobotanic physico-geographic regionalization.

All the colour maps of potential natural vegetation have been neatly published and evenly printed with good register.

* * *

The field mapping of the map of potential natural vegetation of Poland has made it possible to prepare a vegetation map at medium and small-scale. Transition from the scale of 1:100 000 to 1:300 000 or even 1:500 000 is possible by means of photoreduction (Faliński 1971).

The discussion on making a small-scale vegetation map has revealed a number of controversies and doubts whether it is possible to present plant communities by generalization at scales smaller than 1:500 000. There was a suggestion that at those scales complex units or regional units should be used. Those doubts rest on the following theoretical grounds:

Small and medium scales call for not only quantitative but also qualitative generalization. However, qualitative generalization is not feasible since syntaxonomic arrangements of communities in the rank of groups into higher units, i.e. combinations, orders or classes, do not actually produce generalization or simplification of the picture. In the terrain, plant communities of taxonomically distant units occur side by side; and on the other hand, the same class phytocenoses are frequently scattered long distances away from each other. W. Matuszkiewicz (1979) believes that spatial complexes, types of landscapes or even natural regions can be presented at medium and especially small scales.

The above thesis suggests that vegetation maps are a group of cartographic works which is ruled by separate principles different from the ones which rule all other maps of elements of natural environment. W. Matuszkiewicz's thesis does not seem right to me. On the basis of general knowledge about generalization, I tried to generalize the contens of the map of potential natural vegetation of Poland from the scale of 1:300 000 to 1:1 000 000 and to 1:2 000 000. I applied methods generally adopted in cartography trying to get the main thresholds. The paper *A Generalization Study of Small-Scale Vegetation Maps* (Plit 1981) describes in detail the procedure and the results of the generalization. A two-

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-colour map of a part of Eastern Poland (20 per cent of the country's area) has been supplemented to it. Two stages of simplifying the content of the map of potential natural vegetation have been presented there.

The application of the universality criterion to generalization of vegetation maps is purposeful for small scales under 1:3 000 000. The criterion of regional types completed with the pecularity criterion seems to be the best for larger scales. The main assumption of this generalization was the expression of geographical and multi-stratum changeability of plant communities (i.e. the grasping of regional characteristics and the presentation of typical structures, especially structural directions). Quantitative relations between areas covered by individual plant communities have been considered less important.

The legend of the two-colour map was slightly reduced, from 38 symbols on the 1:300 000 scale to 35 on the 1:1 000 000 scale, and to 21 on the 1:2 000 000 scale map. Units corresponding to plant groups were distinguished in the generalization. Synthetic units where different plant communities were joined together were established only in vital cases. A large number of symbols were presented with the help of the symbol method.

The maps have undergone a far-reaching quantitative generalization, line simplification and omission or merger of small separations. The graphic design of the legend was adjusted to a concrete map. Symbols are grouped in families, analogously to the way syntaxonomic plant communities are grouped.

The two-colour 1:1 000 000 map of a part of Northern Poland supplemented to this paper is a further elaboration on the issue of generalization possibilities and the capacity of vegetation map. I attempted to work out a simplified picture of vegetation so that the level of generalization would be the lowest possible and yet the map would be legible. I distinguished units corresponding to vegetation groups. The number of symbols in the legend dropped by one only as compared with the 1:300 000 map legend. The symbol for industrioclimax occurring in small areas was omitted. All the communities were presented at a changeability scale analogous to general map (e.g. the differentiation of hornbeam and oak forests by geographical varieties and generosity forms was marked). A number of symbols were presented in a point symbol form.

Quantitative generalization created a considerable difficulty in preparing this map. I tried to preserve the features of structures of particular regions: characteristic alignments, the degree of fragmentation of separations and typical proportions of areal share of components. As a result, the degree of generalization of this map is considerably lower than on the black and white map (at an analogous scale). Lines are more varied, separations are smaller.

The map (Fig. 3) [1] was made not only hecause of theoretical and practical work on generalization. Basing on this map, I would like to discuss the sense of the general map of potential vegetation and the obviousness of conclusions thereof (that is why thise part of Poland was chosen).

The general map of potential natural vegetation of Poland is sceptically received among physical geographers. Reservations arise as concerns particularly the way of mapping and the fact that the map of potential vegetation is a re-constructive map, based (when the natural vegetation

[1] Figure 3 is enclosed separately under the back cover.

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has been destroyed) on the interpretation of sites and on the areas of substitute communities.

Thematic general maps are based almost exclusively on fragmentary research and interpretation of observations (geological stripping and drilling and soil analyses) to cover bigger areas. Geological, soil, geomorphological, and hydrographic maps were prepared in this way. Therefore the analogous way of accumulating information for the general map of vegetation should not raise doubts.

The interpretative character of the map of potential vegetation does not in any way mean that the judgement is arbitrary and that the picture of vegetation all over Poland is easy to predict or that the map would not differ much from the maps of natural environment.

The map of potential vegetation invalidates many stereotyped notions about the vegetation of Poland (see the enclosed map, Fig. 3). It turns out that Poland is dominated by broad-leaved forests i.e. hornbeam and oak forests, beech forests, oak forests and riparian lowlands, and not by pine, spruce and mixed coniferous forests. The presented part of Poland's territory contains some large coniferous forests such as *Bory Tucholskie*, *Puszcza Kurpiowska* and *Puszcza Kampinoska*. Pine and mixed coniferous forests do not constitute more than 1/4 of the map area. This proportion is not larger for the whole territory of Poland.

The vegetation in the Polish Lowland changes in quality along the line of the lower Vistula and *Bory Tucholskie* to the Noteć and the Warta Rivers. It separates subatlantic beech landscapes from the hornbeam and oak forests which cover the rest of the country. The Northern Divide traditionally drawn meridianally near Olsztyn differs only geobotanically by geographic variations of hornbeam and oak forests and pine coniferous forests.

Vegetation changeability is much bigger than expected. The vegetation not only responds vividly to site microstructure (change of substratum, humidity or exposure) but also forms large spatial combinations. An interpretation of large structural forms is not easy. Relationships between potential vegetation and environment elements is rarely simple (if *A then B*), separated regions more often correspond to physico-geographic or soil regions.

The map of potential natural vegetation is one of the maps of elements of natural environment. It contributes valuable information about the living world. The legend of the map uses the language which is abstract to an average user. In time, Latin names for plant communities will become as clear as the language of geological maps. The content of the vegetation map will then be intelligible to everybody.

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# CARTOGRAPHICAL METHOD OF RESEARCH USED IN INVESTIGATION OF CHANGES IN GEOGRAPHICAL ENVIRONMENT

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The cartographical method of research, understood as analysis of maps from the viewpoint of their utilization, plays an increasingly important role in contemporary cartography, especially cartography treated as an independent branch of science. The cartographical method of research seems to attract the interest of cartographers in an equal measure as the methods of map elaboration. This is understandable when one considers the recent major progress of the latter, due, among other things, to the automation of map making processes, the introduction of new techniques of data collection, such as remote sensing, etc. As Berlant (1978) rightly said of thematic maps, both of natural environment and socio-economic ones, the study of maps starts already at the stage of field mapping, i.e. at the time when they are being elaborated. Hence it is difficult to draw a clear-cut boundary between map study and map elaboration. However, mapping should not be interpreted merely as the procedure of plotting facts and data observed in the terrain or recorded in some other way on the topographic basis. Nowadays nearly all thematic maps are based on field mapping and at the same time derived from other, related maps. The boundaries between the two sources of map content are specific of different types of maps and there are no universal requirements in this respect.

Moreover, in view of the considerable complexity of problems covered by individual maps, which is due to the general progress in science and technology, the vast majority of thematic maps cannot be limited to a presentation of the problem contained in the theme. They should be presented against a beoader background, which belongs to the sphere of other branches of science; besides, a contemporary map is expected to provide a more synthetic and comprehensive approach. Naturally, a synchronization of the content of related maps is of fundamental importance (Trafas 1971; Zarutskaya 1966).

A specific derivation of the content of one map from the content of another, characteristic mainly of thematic maps of natural environment, is a good example of links and correlations, a reflection of those occurring in nature. When the shapes of outlines of some discrimination areas are co-ordinated at the stage of mapping, existing maps are used, which is tantamount to some form of studying (using) them. During field geomorphological mapping, for instance, a geological map is used to determine ranges of alluvial or glacial deposits. Thus, mapping may be considered one aspect of the cartographical method of research.

The situation is somewhat different in the case of methods of carto-

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graphic presentation, which provides the transition from reality to an abstract model in the form of a map. In this case the content of the map is analysed — if at all — merely from the viewpoint of an application of one or another method for the presentation of the given phenomenon, which by its very nature limits the applicability of methods to just a few variants. The nature of the presented problem largely determines the method of presentation, which would become an end in itself were it not for the requirement of correctness of subsequent map analysis, which is the core of the cartographical method of research. On the other hand, the selection of an appropriate method of presentation, its adaptation and the experiments involved should probably be labelled as research, but should not be included in the cartographical method of research. Finally, it must be added that, although mapping shaves many features, when it comes down only to an inventorying or locating facts on a map, it has little in common with this method.

One of the most important functions of the map in geographic sciences is assistance in the determination and explanation of geographic regularities, particularly as concerns the distribution of and correlation between phenomena. This role of the map is particularly important in the study of the geographical environment, where fundamental significance is attached to aspects of links between individual elements (components) on the one hand, and the comprehensiveness of the picture obtained on the other. Moreover, the cartographical method of research seems particularly useful and sometimes indeed the only feasible method in the investigation of the geographical environment, which is subject to constant changes due to natural processes and man's activity. Thematic maps of individual elements of the geographical environment are important source material and research tools for many branches of science and for practice.

Treating map analysis as an aspect of the cartographical method of research, one should not limit it to an interpretation of only this content which directly confronts the user. There is another plane of more covert content which is not revealed until the map is studied in detail. Often it is enough to look at the map not from a narrow viewpoint, but in a more versatile way, or even from a position of another specialist (e.g., to assume the perspective of a geologist when examining a geomorphological map or conversely, the perspective of a geomorphologist for the examination of a geological map) to discover entirely new content in it. To reveal this content is also a task which falls within the cartographical method of research. Naturally, the most popular and repeatedly tested method of investigating a problem is that of using a series of maps with complementary content.

However, a major difficulty is the nearly universal lack of consistency as regards the outlines of correlated phenomena on related maps. As a matter of fact, this consistency may only be expected in atlas publications, and that, too, is not always the case.

Comparative studies of maps are predominantly of a static character, i.e. they investigate phenomena as they occurred at the moment of mapping. Conclusions from such an analysis are often erroneous, for they are drawn from a comparison of maps frequently made at very different times, at different scales (with a different degree of generalization), on different geographical bases, etc. In principle, some dynamic element is inherent in such cartographic material, for it may be assumed that the

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possible differences or lack of consistency between images on two maps are also a consequence of some changes which occurred in the interval between the making of each map, e.g. change of land use results in changes of soil, so outlines on a soil map made after those changes took place will not refer to the range of some Quaternary deposits, etc.

As concerns the study of changes in the geographical environment, the cartographical method or sesearch is irreplaceable whether using general geographical (topographical) or thematic maps, as map is the best testimony to the state of reality at the moment when it was made.

Changes under way in the geographical environment may be observed by way of analysing maps which date from different moments in time (mainly topographical maps) or by studying the correlation of discrimination areas on thematic maps.

## STUDY OF MAPS DATING FROM DIFFERENT POINTS IN TIME

Apart from changes effected by man's sudden interference (industrial ventures, the construction of highways, dams, etc.) the pace of changes in the geographical environment is very slow. Even rivers, the most mobile of natural elements, do not change their run in a marked degree for whole decades, though as concerns the river channel itself, important changes take place after each flood, particularly in the upper part of the river and where it flows on a rocky bed. Those changes are recorded during irregularly performed geodetic surveys, and the scale of contemporary cartographic presentations (plans) is such that one cannot expect to find any archival records of similar kind. In their central or lower run, rivers meander or flow in a straight line (or approximate to a straight line); less frequently they are anastomotic. Natural changes are very slow and are chiefly accelerated by means of regulation work, particularly the digging of ditches, which shorten the run of the river. When that is done, changes occur not only at the place where the ditch has been dug, but also up and downstream. This is due to a greater fall of the river, and consequently its greater energy. The run of the river can also be shortened by a natural breaking of the 'meander neck' during freshet; the results are the same.

When one uses maps dating from different times to determine the direction and pace of changes, one should bear in mind the following facts:

— the value of archival maps diminishes as the time when they were made grows more distant,

— maps refer to accidental situations and are not related to any change of the situation in the terrain (topographical surveys were mainly conducted for military purposes),

— different maps are made at different scales (as concerns Polish archival maps, they were also made in different measure systems), they have different degrees of reliability, different keys and symbols.

For the above reasons, any study on old map material must be preceded by an analysis of their reliability. Thie analysis should include a comparison of distances, azimuths or angles and scales on old maps and on the modern map, which is considered free of mistakes. Subsequently the errors which characterize the reliability of individual maps are computed. They are: the mean real distance error, the mean relative error, the mean error of azimuths and angles, and the mean positional error. When the errors are very big, the maps should not be compared, as the differ-

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ences determined by means of this comparison (e.g. as concerns lines representing edges of inland waters, the river run, forest area borders, etc.) are not a consequence of changes in the environment, but of those errors.

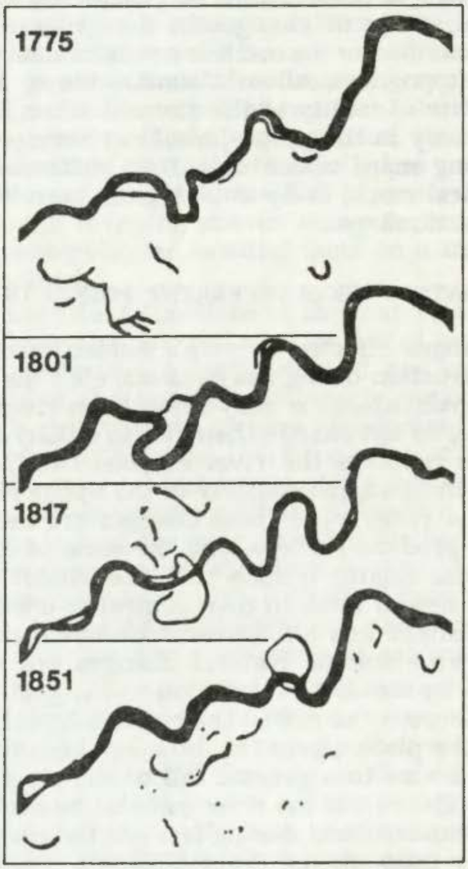


Fig. 1. Part of the Vistula River run east of Cracow on maps dating from different times

In order to reconstruct changes in the Vistula River channel east of Krakow, in the 1970s the author of the present paper conducted comparative studies of topographic surveys of this part of the Vistula made in the years 1775, 1801, 1812 and 1851; the current state was determined on the basis of aerial photos (Trafas, 1975). Those maps[1] were originals or photocopies of manuscript maps made at different scales (1:14 400, 1:21 000, 1:28 800) by topographers representing not only different countries (Aust-

[1] A topographic survey of Galicia at the scale of 1:28 800 conducted under the supervision of Maj. Mieg and Maj. Waldau in the years 1775–1783. Topographical survey of Western Galicia at the scale of 1:28 800 conducted under the supervision of A.M. von Heldensfeld in the years 1801–1804. *Carte générale du cours de la Vistula depuis Cracovie jusqu'a Thorn dressée au Bureau Royal topographique*, 1817, scale ca. 1:21 000. *Uebersichts Plaene Weichsel Stromes und seines Innundations Gebietes von der schlesischen Graenze bis zur Ausmuendung des Dunajec Fluses*, 1851–52, scale 1:14 400.

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ria, Russia, France, and by Polish engineers specializing in topography), but also different schools of surveying. When undertaking a comparison of those maps, first of all the real scale of individual maps had to be determined. It turned out that not all the scales quoted on the maps agreed with the actual measurements. This must have been a consequence of the paper's shrinking or the method of copying. It was not until then that the above mentioned errors were computed and it turned out they were approximately the same on all the investigated maps.

Figure 1 illustrates the changes of the Vistula run along the selected segments. On the basis of comparative studies of series of maps deriving from different periods, graphs and histograms may also be made to illustrate the changes. Figs. 2a and 2b illustrate the changes in the length and the radius of curvature of meanders of the Vistula for different periods. Given the distance in time between the surveys (maps), one can compute the pace of changes, such as the retreat of the banks over the period of one year, and the like. However, it must be remembered that the distance computed from the map has to be bigger than the positional error on the map. It is also important that one can define the cyclic and the repetitive character and the rhythm of the investigated phenomena.

On the basis of maps dating from different times, one can also construct other, derived maps. Regardless of the type of the investigated maps, they should be classified as thematic maps. Thus, for instance, a map of changes in the Vistula run over the last 200 years, a sample of which is presented in Fig. 2a, was constructed on the basis of the above mentioned maps. The hypsometric map, for instance, is the source of various morphometric maps (maps of slopes, relative relief, morphoisohypses, etc.). Those maps differ from the initial maps not only by their new content (quality), but also by the method of presentation; most often they are isopleth maps, which depict the volume and direction of changes, translocations or deformations: thus the form and the content of the map is transformed, which is another attribute of the cartographical method of reseaarch. As concerns the aspect of changes in the geographical environment, a typical example is the map of relief deformation which in a simplified from was published in the *Atlas of Katowice Voivodship* (1971).

As the methodology of cartographical presentation is concerned, the prevalent kind are the so-called maps of areas of changeablity of phenomena, on which different colours or patterns are used to show the character of changes of a phenomenon in the given area. This approach clearly presents the dynamics of change. For instance a series of synoptic charts made at different times, allows one to examine changes in climatic elements and thus predict future trends. Generally speaking, maps which provide a synthetic image of the dynamics of change in the past are a basis for the prognostication of future change trends; thus one can pass from historical to prognostic maps.

The study of topographical and thematic maps aimed at a reproduction, evaluation and prognostication of changes under way in the geographical environment will never be invalidated, and the rank of the cartographical method of research applied for this purpose will grow together with the expanding prospects for special mapping and the making of maps at specified periods (e.g., every some years or at a specified point in time) and owing to the fact that aerial and satellite images may speedily be obtained theoretically at any time.

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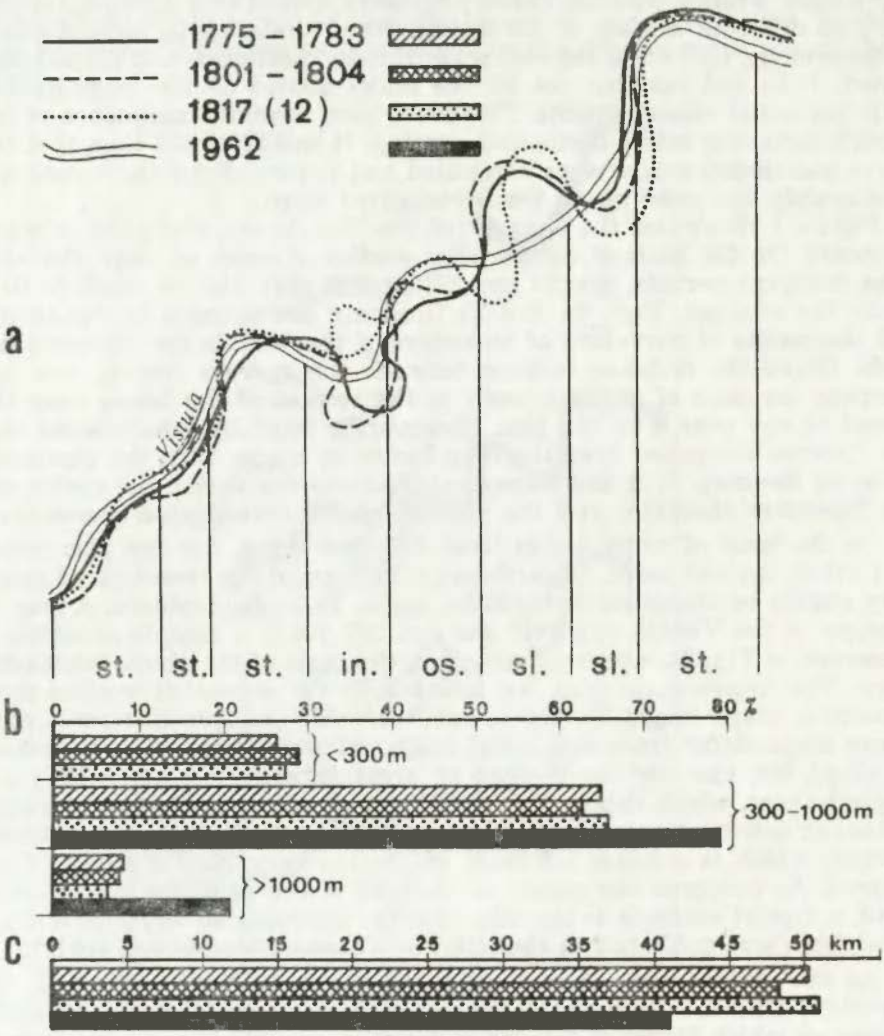


Fig. 2. a) Excerpt of map of changes in the run of the Vistula channel east of Cracow. Types of changes of meanders: st. — stable, in. — inversive, os. — oscillating, sl. — slope. b) Histograms illustrating per cent shape of three classes of meanders of different radii of curvature (300 m, 300-1000 m, > 1000 m) at different times. c) Changes in the lenght of segment of the Vistula River between Cracow and the Raba River confluence, on the basis of cartometric measurements on different maps

## STUDY OF A SERIES OF DIFFERENT THEMATIC MAPS

An analysis of different thematic maps seems to be of lesser importance for the investigation of changes in the geographical environment. However, this belief is only superficially correct. Obviously, it would be hard to draw conclusions from a comparison of qualitatively different maps. However, assuming that thematic maps of natural environment, and at least some of them, should be consistent with each other, i.e. they should reflect the correlations existing in reality, the bringing to light of elementary inconsistencies may testify that changes have been or are under way. A pre-condition for the validity of such an interpretation is absolute cartographical correctness, which has to be the case in the elaboration of atlases and monographs, when one team of authors is able (though by no means always) to satisfy this condition.

An examination of changes in the geographical environment in this way is an activity which falls under the cartographical method of research, the aim of which is to explain and analyse the relationships and mutual influence of phenomena presented on different maps and to elaborate a synthesis.

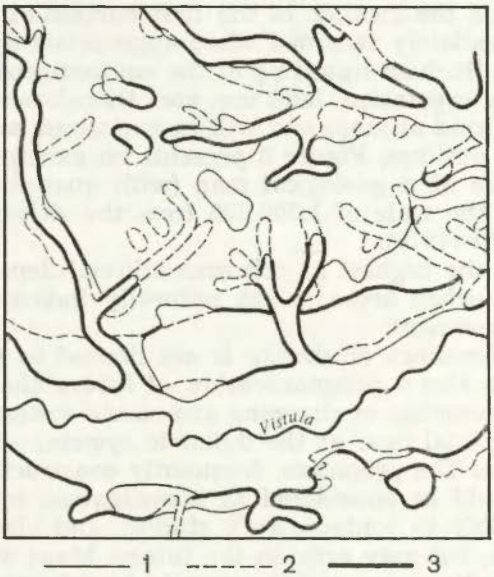


Fig. 3. Excerpt of map of the entropy of outlines of a soil map and a geological map (Cracow area)
1 — outlines from soil map, 2 — outlines from geological map, 3 — consistent outlines

There are a number of methods for the presentation of correlations between phenomena. The most important of them are qualitatively new maps: isocorrelates, choropleth maps of correlations, maps of regions of different degrees of correlation, residuals of regression, and entropy of outlines (Berlant 1980). This last type of maps seems to be the most useful for the analysis of environment dynamics on condition that the outlines of discrimination areas are not influenced by such factors as different degrees of generalization, the failure to maintain consistency, etc., which has been discussed earlier. Maps of entropy of outlines make it possible to assess the degree of consistency of every elementary outline. Zero entropy, which denotes absolute consistency, is an extremely rare case and occurs only when there are no changes in the environment. Changes occur together with growing entropy, but it should not be simply inferred. that changes have taken place wherever entropy $E > 0$. Changes may have taken place and the very indication of such areas is a certain success of the cartographical method of research in the investigation of the dy-

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namics of the geographical environment. The occurrence of entropy should then be justified, usually by means of another thematic map, e.g. entropy of outlines on a map of soils and quaternary deposits may be explained with the use of a map depicting devastation of soils, and then one is dealing with changes. If the map does not confirm the occurrence of entropy, or if it is too big, it is not a case of changes.

The changes themselves, which may sometimes be accidental, take place, generally speaking, either suddenly (and then are usually irreversible) or gradually. The latter are more difficult to examine on thematic maps due to their short history — the oldest thematic maps are some 150 to 180 years old. On the other hand, a sudden change, such as the construction of an artificial reservoir on a river, may involve instant changes in, for instance, the location of the first horizon of underground water, which is immediately recorded when appropriate hydrographic mapping is conducted. Such an upsetting of the environmental balance affects the image of soils, vegetation, land use, etc., therefore some changes will also occur on this kind of maps and will be expressed, among other things in the entropy of outlines. Figure 3 presents an excerpt of a map of the entropy of outlines of a geological map (with quaternary deposits) and a map of soils at the scale of 1:300 000 from the *Atlas of the Municipal Cracow Voivodship* (1979).

Consistency is the highest as concerns alluvial deposits and muds, it is the smallest in urban areas, which naturally indicates changes in the geographical environment.

The issue of dynamics of change is not limited to reconstructions of past changes, it is also a prognostication of future change. The starting point is the determination of changing and stable systems; the latter may be considered a special case of the dynamic system, where the function of time is constant. The prognosis, frequently constructed in the form of a hypothesis, should be considered as investigation into a phenomenon which is inaccessible to contemporary studies, and also one that has so far been unknown, but may arise in the future. Maps which assess changes lead to prognostic maps, and the practical application of the latter is constantly increasing.

Finally, it is worth mentioning that new prospects are opening up before the cartographical method of research for the investigation of environment (landscape) dynamics, due to the increasingly common utilization of aerial photos and satellite images. Apart from the important fact that repeated satellite images in systems such as the LANDSAT can be obtained at specified intervals, the optical generalization of outlines of the depicted objects and phenomena is also of importance. Owing to the fact that this activity, in this case automated, is freed from subjective influence, greater prospects open for comparative studies and the risk of mistakes is reduced for map users. In its development, the cartographical method of research must rely on the remote sensing methods.

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# PROBLEMS OF CARTOGRAPHIC PRESENTATION OF MAN-ENVIRONMENT INTERACTION

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One of the essential tasks of geographers who investigate the man--environment interactions is to express the discovered facts and relationships in various forms of cartographic presentation. This is an immensely difficult task, as neither is the object in question, i.e. man's environment, sufficiently known nor are the existing cartographic studies appropriate for the assumed objective. This is to be attributed first of all to the fact that, while the interrelations between man's activity and the environment are of a dynamic character, the majority of cartographic presentations present a state at a moment in time and are intended to be static.

Since the interrelations between man and his material environment are very complex and involve nearly all of the variables of the two interacting systems, one should not hope that a comprehensive presentation of them can fit on one map. The reverse is true, if our studies are to be of use, we should opt for a number of presentations. Only when taken together they would provide a picture of the changing reality. In other words, the goal should not be a single map, but an atlas, a set of maps.

The existing cartographic presentations relative to the man-environment system can be arranged by the degree of their complexity, completeness and comprehensiveness. This will provide for a classification system of environment maps, an outline of which will be presented below.

1. Comprehensive presentations those which present on a single map the largest possible (from the viewpoint of cartographic techniques) number of phenomena relative to various factors of the man-environment relationship.

1.1. Comprehensive presentations of 'field survey' type, which illustrate the state, intensity or directions of interaction at the time of study, i.e. at $t$ time.

1.2. Presentations of the type of comprehensive parahistorical analysis which present changes that have taken place in the man-environment relations from a certain point in the past till now, e.g. over the last five or ten years, i.e. the relations between a definite $t_{-1,2,..-n}$ time and $t$ time.

1.3. Comprehensive historical presentations, which illustrate the relationships in question in distant or recent past, i.e. in $t_{-n}$ configuration.

1.4. Comprehensive presentations of a prognostic (predictive) type, which on the basis of parameters of the man-environment system predict changes of states of the system in the future, i.e. $t-t_{+1,2,..+n}$ configuration.

2. Indicative presentations, which provide a complete qualification

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of the investigated phenomena comprehensively, on the basis of changes of states of factors with the highest indicative properties, in other words, factors with maximum superinformativeness in the given configuration.

2.1. Current indicative presentations of 'field survey' type, which present directly the state of given factors and indirectly a complete image of man-environment interaction at $t$ time.

2.2. Parahistorical indicative presentations, which describe the relevant changes which have taken place from a time in the past till the present, i.e. relations between $t_{-1,2,..-n}$ and $t$.

2.3. Historical indicative presentations, which deduce about the state of superinformative factors in the past, i.e. at $t_{-1,2,..-n}$.

2.4. Predictive-prognostic indicative presentations, which forecast changes in the man-environment system from the states of superinformative factors in distant or recent past in comparison with the current state, i.e. in $t_{+1,2,..+n}$ configuration in relation to $t$.

3. Analytic studies, which describe single interactions severed from the entire context of man-environment relations in a donor-taker system; the interactions may be regarded in the following ways:

3.1. The donor, i.e. man's influence, may be regarded comprehensively, the taker may be a single element, feature or property of man's physical environment,

3.2. The donor is of an elementary character, i.e. it is relative to some form, technique or intensity of influence on the environment, whereas the taker is of a comprehensive, complete character.

3.3. Both the donor and the taker are single, elementary phenomena.

Eeach of the above listed types (3.1., 3.2., 3.3) may be regarded in the categories of the present ($t$), in parahistorical $t_{-1,2,..-n}(t)$, historical ($t_{-n}$) and prognostic $(t)t_{+1,2,..+n}$. That provides for 12 different combinations, each of which has its significance and value in the investigation.

4. Synthetic studies, which present with the use of cartographic techniques not the perceived reality, but its logical or mathematical, conceptual generalizations. Various levels of generalization are applied in this approach, from the most primitive divisions into quality clases and summational generalizations to very subtle quantitative methods. Also in this case the above listed four temporal types may be distinguished, i.e. current, parahistorical, historical and predictive-prognostic presentations.

In the to-date practice of environmental cartography special attention has been paid to improving the methods of the comprehensive approach (Faliński 1975). It has been the goal and often the ambition to provide for maximum saturation of the cartographic work with information. Unfortunately, experience has shown that this was not the right way. The even-larger number of variabes, a simultaneous application of different cartographic techniques or a descriptive inflation of the legend often resulted in a total unintelligibility of the map. In consequence of disregard, and often actual ignorance of the psychological conditions of perception and elementary principles of the information theory, the map user ended up with 'information noise' instead of the desired information. It is improvable that anything else is to be attained by proceeding along this path. Likewise the informative and practical value of this type of presentations does not seem to be growing proportionally to the degree of complexity. It is rather to be expected that regardless of what technique will be used: further inflation of the legend, the superimposition of successive

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traces or the like, the usefulness of comprehensive aproaches will decrease. Two reasons are responsible for that: firstly, the huge complexity and complication of the phenomena and relationships shown, which simply cannot be presented on a map all at the same time, and, secondly, the frequently synergic action of forms or types of antropo-pressure, in consequence of which individual actions do not always cumulate, but form a redundant combination or neutralize each other (in other words, in the man-environment system two minuses not always make a minus). A cartographic presentation thus obtained is not only poorly legible, it is actually. It is a reflection of our convictions much more than a picture of the reality. An information deficiency is frequently responsible for the fact that studies of this kind feature not the most important, but the most easily available data.

The indicative presentation is based on two axioms: 1) there are links and interrelation among all the elements (components) which make up the ecological-geographical system of nature (ecosystems, landscapes, biomes, etc.), 2) there exist in nature some elements with particularly high superinformative properties.

A thorough investigation of geosystems has shown that they consist of two separate groups of elements, as it were. One is those elements which shape the structure of the geosystem and form the framework for all phenomena which occur in it. The other, a delicate tissue on the earth surface, cumulates, as it were, all information on all the transformations that the geosystem undergoes. The first group contains elements which form the core of the geosystem, such as the physical properties of the geological substratum, especially relief, variables of the atmosphere, hydrosphere, man's activity, etc. The second contains elements of the biosphere, in particular vegetation and soils, and sociosphere, especially the biological and cultural state of human population.

While a thorough knowledge of geomorphological structures and processes, i.e. the fundamental, natural elements of the geosystem provides for a precise determination of the state of some 30 per cent of the remaining components, information contained in the vegetation provides for a precise evaluation of as many as 84 per cent of those components, and in soils, of 78 per cent. Together the soil and the vegetation determine as many as 97 per cent of all the variables of the geosystem. In other words, the superinformative properties of the biosphere, which provide for determining the characteristics of the system, are three times higher than those of its remaining components. This enabled researchers to limit the sphere of investigation to superinformative elements and indirectly, through them, determine the state and behaviour of the remaining components and analyse the changes of the geosystem as a whole.

The superinformative properties of the vegetation-soil compound relate not only to the natural component of interaction of the man-environment system, but also to most forms of man's economic activity, especially the forms of land use which are known as biogenic, i.e. agriculture, forestry, the management of water resources, recreation, etc. This provides for extending the indicative evaluations obtained in this way to embrace the whole man-environment system. This is nothing new, as bioindicative and pedoindicative research and inferences thereof have long been applied in economic activity. The methods of evaluation and quality classification of arable land based on bioindication are generally known

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and so are methods of evaluating the degree of air pollution through an analysis of the species composition and the physiological state of lichens. Biological methods of evaluating the purity of waters, the productivity of forests, etc. are well-known and used.

One of the unimpeachable advantages of using living organisms as indicators of the state and changes occurring in man's environment is the large number of species (and individuals) which make up biological and spatial communities. Each plant and animal species has its specifically unique amplitude of ecological requirements as regards all of the environmental conditions, therefore they do not occur in space incidentally. On the contrary, they form more or less closed, repetitive communities. Every, even a minute change in the parameters of environment state is immediately reflected in the structure, the species composition and the physiological state of the community. This provides for an unequivocal determination, evaluation and prognostication of directions of those changes in the whole prognostication of directions of the changes in the whole environmental complex.

The fundamental phytoindicative study of the current state of the environment is a map of today's potential natural vegetation the principles for which were elaborated by well-known German geobotanist Professor Reinhold Tüxen (1956). This map indicates not so much the current state of vegetation (as other presentations serve this task) as the present, contemporary state of the geographical environment as a whole.

The current state of vegetation is presented by diverse maps of real vegetation. Usually they are of the 'field survey' kind, so in themselves they do not provide information about the dynamics of processes under way in vegetation or in the environment. With an eye to investigating those processes, a method for the evaluation of the so-called information content has been elaborated (Kostrowicki 1976). This content is computed for each phytocenosis with the use of the following formula:

$$J = \frac{h(l_1 i + l_2 i + l_3 i + \ldots + l_n i)}{100},$$

where: $J$ = total information content of the phytocenosis, $h$ = maximum hight of plants forming the phytocenosis $l_1$, $l_2$, $l_3$, $l_n$ = number of plant layers which make up the phytocenosis, $i$ = information content of each layer taken separately, computed from the formula:

$$i = \left(\frac{S_d^2 + S_d}{2} \ln p\right) + (S_a \ln p),$$

where: $i$ = information content of plant layer, $S_d$ = number of dominating species (with individual terrain coverage over 5 per cent), $S_a$ = number of accessory species (with individual terrain coverage under 5 per cent), ln $p$ = natural logarithm of total terrain coverage by the given quantity group.

The results obtained in this way and transferred onto a map will indicate directly the internal differentiation of vegetation, the hight, density, abundance of plants, etc.

The index of information content ($J$), computed separately for individual ecological and geographical groups (e.g. for plants sensitive to certain doses of $SO_2$, to the presence of nitrogen, phosphorus, or potassium in the soil, to weeds, etc.) makes it possible to present on maps the state

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of the environment, the degree of its degradation, and, by comparison to analogous phytocenoses from untouched areas, the directions in the transformations of the investigated configuration. The prospects for interpretation that this method opens are very diversified and their applicability for the analysis of man-environment interaction is very wide. The only shortcoming of this method is the amount of work it requires. It is not fit for a presentation of transformations of the environment in vaster areas. It is more suited for detailed scales, from 1:2000 up to 1:25 000.

For smaller scales another method may be used (Kostrowicki 1973), a method of the so-called vegetation states, based on a physiognomical and structural analysis of the successive stages of its anthropization. A legend to this type of map is presented in Fig. 1.

| states | (a) | (b) | (c,d) |
|---|---|---|---|
| 0 | N | N | N |
| 1 | N | N(J) | N(J.S) |
| 2 | N | N.A(J) | N(J.S.A) |
| 3 | N(J.A) | N.A.J | N.A.S(J) |
| 4 | N.J(A) | N.J.A | N.A.S(J) |
| 5 | J(N.A) | N.J.A | A.S.N.J |
| 6 | J(A) | A.J.S(N) | A.S(N.J) |
| 7 | J | J.A(S) | A.S.J |
| 8 | – | N | N.S(J.A) |
| 9 | – | N(J.A.S) | S.N.A(J) |
| 10 | – | J.S(N.A) | S.A(N.J) |
| 11 | – | J(S.A) | A.S(N.J) |
| 12 | – | J | A.S.J |
| 13 | – | J | A.J(S) |
| 14 | – | – | N.S(A) |
| 15 | – | – | S(N.A) |
| 16 | – | – | S(A) |
| 17 | – | – | S(A.J) |
| 18 | – | – | S.J.A |
| 19 | – | – | J.A.S |
| 20 | – | – | J.A |
| 21 | – | – | J(A) |
| 22 | – | – | A.J |
| 23 | – | – | A |
| 24 | – | – | Z(A.J.S) |
| 25 | – | – | Z |

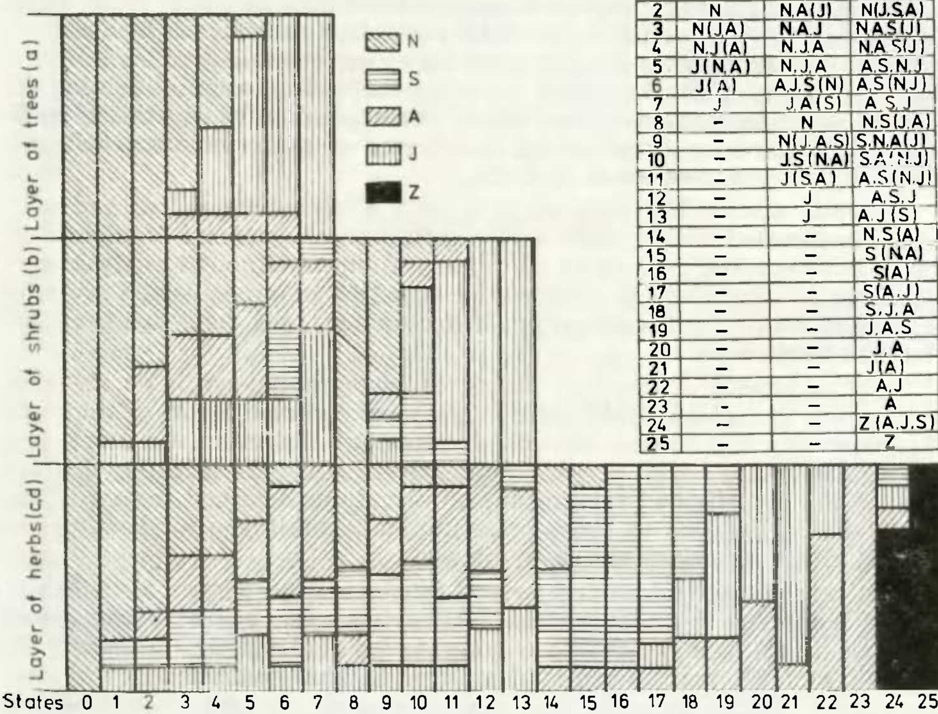


Fig. 1. States of transformation of vegetation cover

*N* — natural vegetation, *S* — semi-natural vegetation, *A* — synanthropic vegetation, *J* — introduced vegetation, *Z* — no vegetation

The figure illustrates the interrelations between the layer structure of vegetation and the four genetic groups of plants which make up this structure. They are: natural vegetation (*N*), which forms primary systems and agrees entirely with the environment potential; semi-natural vegetation (*S*), which occurs as an addition in natural plant communities and spontaneously overgrows deforested areas; introduced vegation (J), i.e. vegetation artificially introduced by man, and last, synanthropic vegetation (*A*), i.e. all sorts of weeds.

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Vegetation states from '0' to '7' indicate different stages of deformation of forest vegetation; states from '8' to '13' indicate individual stages of anthropization of shrub communities, from nearly natural groups to artificially cultivated plots of fruit shrubs.

States from '14' to '24' illustrate successive degradation changes of grass communities deprived of trees and shrubs, state '25' indicates an area totally deprived of vegetation.

Maps of vegetation states (anthropization stages) may be plotted relatively easily for larger areas. They correspond to general scales, from 1:25 000 to 1:100 000. An indicative interpretation of those maps is naturally much more limited, more general than in the case of those mentioned before. However, they do provide a lot of useful information about the overall state of the environment and the transformations to which it is subject.

Indicative-geobotanical presentations at smaller scales, in the order of 1:300 000 to 1:3 000 000 require a totally different approach. Those maps do not deal with vegetation, but with vegetation complexes (landscapes). Methods for the making of such maps have not been elaborated in sufficient detail yet. Faliński (1975) made an interesting attempt in this direction, when he presented the state of anthropization of vegetation landscapes in Poland on the basis of the degree of preservation of natural, semi-natural and man-made systems.

Analytic approaches may be of a very different character and may relate to detailed issues, such as the influence of artificial fertilizers on water environment, as well as more general ones. Although analytic cartographic presentations illustrate only a section of a problem, they may be of great value for investigation. Unfortunately, not many maps of this kind are made here.

It is extremely difficult to elaborate cartographic-synthetic methods adequate to the investigated reality. The most common forms of this type of presentation are diverse choropleth maps and diagrammatic maps, less common are maps which present summative quality classification evaluations of the investigated relationships, evaluations obtained from qualitative features. Legends to those presentations contain the total value expressed either descriptively or in figures.

Another synthetic approach which illustrates the degree of deformation of landscape is a simple technical cartographic operation suggested by Janecki (1978). It consists in a computation of the share of straight lines visible on the map in the total number of lines contained in the map. The author rightly assumed that nature 'abhors' straight lines, so those visible on the map are man-made. Janicki computed the share of straight lines on topographic maps at scales of 1:25 000 and 1:100 000 for squares with 1 km side and in this way obtained a very interesting and instructive diagrammatic map, which gives a synthetic view of the transformation of natural environment, albeit it does not investigate the causes of this transformation. The drawback of this method is the fact that, although all straight lines are surely man-made, so are some of the curved lines. Thus, the diagrammatic map does not present the overall picture of interactions, but more of a style, a method of development of space by man. When this method is used, a similarly transformed area in the lowlands and in the mountains will produce a completely different cartographic image.

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Another kind of synthetic cartographic presentations are those based on mathematical analysis and processing of quantitative data, typical of economic-geographical studies. However, it is difficult to apply this presentation in environmental cartography, due mainly to the lack of reliable quantitative data.

There are diverse other methods of a synthetic evaluation of the man-environment interaction basing on quantitative data. The best known of them is the assessment method offered by Pickering (1978). A method offered by the author of the present paper is somewhat similar to Pickering's. Its general formula is expressed in the following equation:

$$A = \sum_{i=1}^{N} X_i + \sqrt{md + mr} + p + g + z^2,$$

where $A$ = index of environment transformation in $i$ square, $X_i = ps_i$, in which $s$ – valour of anthropization state in the following arrangement: 0 = natural community, 0.5 = natural forests with introduced individuals, 1 = planted forests (man-made), 1.5 = semi-natural brushwood, 2 = planted brushwood (young stands, etc.), 4 = meadows and pastures, 5 = orchards and shrub plantations, 6 = arable fields, 7 = spontaneous vegetation in transformed sites, 10 = no vegetation (less than 10 per cent of the area);

$$p = \frac{\text{area of each state}}{10},$$

$m$ = number of months in the year (quarters of year) when the given area is penetrated by the population, $d$ = number of permanent inhabitants, $r$ = number of temporary dwellers (e.g. tourists)

$$p = \frac{\text{built-up area (under buildings)}}{10}.$$

Note: If there are multi-story houses in the square, each story counts separately

$g$ = area of changes in the terrain morphology, $z$ = quality classified index of pollution computed for the whole square in the scale from '0' (no pollution) to '5' (very strong pollution) in the configuration $(a^2 + h^2 + l^2)$, where: $a$ = air pollution index, $h$ = water pollution index, $l$ = index of earth surface pollution with waste, chemicals, etc.

The above presented formula is in principle suited for scales from 1:10 000 to 1:100 000. Work is now under way on such modification of it which would provide for its applicability to smaller scales (from 1:300 000 to 1:1 000 000).

Finally, the issue of preparing cartographic presentations of the man-environment problematique in a dynamic approach should be raised. With the exception of the approach based on the computation of information content, most of the above presented solutions are of a static character. The only way to make them dynamic, i.e. to present changeability over time, is to repeat them at some time intervals. By comparing maps of the same area prepared with the use of the same method, but at different times, one can observe the directions and intensity of transformations and draw conclusions thereof on the development trends of the investigated territorial man-environment system. Though principally correct,

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this procedure requires time and gives no grounds for predictive inferences. On the contrary, an application of it will provide what is virtually a typical parahistorical study. An extrapolation of the observed development trends in the future is a risky operation and, like every extrapolation, lacks reliability. The only methodological solution which seems feasible in this case is the construction of a map or maps of development trends, which will not depict changes in the distribution of material structures, but changes in functional interrelations in geographical space.

The author of the paper believes that one of the basic tasks facing environmental cartography is to elaborate a set of methods providing for a truly dynamic presentation of the investigated phenomena.

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# POLISH EXPERIENCES IN LAND USE MAPPING

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## OUTLINE OF PAST RESEARCH

The *Geographical and Statistical Atlas of Poland* published 65 years ago by Eugeniusz Romer opened up a new page in Polish economic cartography (Romer 1916). The 'Land Use' map it contained gave birth to the Polish term for 'land use' and initiated a new type of Polish agricultural maps — the land use maps. Like most of the maps in that atlas, it was elaborated with the use of the isarithmic method and presented the share of arable land in the country's overall area.

The few maps that were subsequently published in the interwar period differed from the modern idea of land use maps. They were maps or landscape plans which presented the distribution of crops, land cover forms or land use orientations. All of them covered small areas and were mostly illustrations to different works, not always devoted to land utilization (Biegajło and Jankowski 1972; Jankowski 1972; Kostrowicki 1961, 1962).

After World War II the plans for the reconstruction of the Polish agriculture from wartime devastation provided a stimulus for the launching of work on a land use map which would give a synthetic presentation of the country's spatial development. Throughout the post-war period researches have been striving to elaborate a uniform survey method for all of Poland's territory. Nearly all field studies, even separate projects covering small areas, served this general aim.

The man who provided most encouragement for this kind of studies was K. Dziewoński, the then manager of the Research Office of the Central Board for Spatial Planning. During his stay in England, be acquainted himself with the *Land Utilisation Survey of Britain*, found it important and valuable and resolved to carry out a similar survey in Poland.

The initial assumptions and method for the survey were elaborated by A. Jahn in the form of draft instruction. The basic map was to be a 1:25 000 topographic map. It was assumed that, after field observations were transferred onto the base map, it would be reduced to the ultimate scale of 1:100 000. When preparing the instruction, the author used the experience he had gained in 1946, when he supervised field work in the Vistula valley between Solec and Dęblin. The maps made in the course of this project, the first land use study after the war, were never published.

Allowing some modifications resulting from the specific character of urban areas, this instruction was used in the years 1949-1950 by a team under K. Bromek, for the elaboration of 1:25 000 and 1:5 000 land use maps

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of Cracow and its closest suburban region. The maps were ordered by local planning offices. Apart from two black samples enclosed with Bromek's paper, the maps were not published (Bromek 1955). A number of maps of different parts of Poland were made when working on regional planning projects; the content of those maps was limited to the plotting of main land use categories (Kostrowicki 1959).

The subsequent survey was undertaken in 1952 under L. Ratajski and covered the areas of Dwikozy, Czachów, Solec and Janowiec (Ratajski 1965). The unpublished maps at the scale of 1:10 000 were drawn on tracing paper; the distinguished land use categories and the approach to colour differed from A. Jahn's instruction.

Those three surveys were virtually all that was done in the period of first attempts at elaborating a method for detailed survey, i.e. in the years 1946–1952. It turned out at that time of acquiring first experiences that a detailed survey of the whole territory of Poland was an undertaking which by far exceeded the organizational, technical and financial opportunities of those years. Therefore the plan to perform a survey of the whole country was adjourned for an indefinite period, though attempts at elaborating a method for such a survey were not abandoned.

In the conviction that indoor work may speed up the making of a land use map of the whole Poland, F. Uhorczak suggested that 1:100 000 topographic maps be used as basic maps for the elaboration of a smaller-scale land use map. The work conducted by a team of several cartographers under F. Uhorczak lasted five years and ended in 1957 with the printing of a set of 1:1 000 000 maps (Uhorczak 1969). These maps will be discussed in more detail later in the paper.

K. Dziewoński initiated a successive attempt at elaborating a method for detailed survey. In the years 1953–1954 the vicinity of Sandomierz was surveyed at the scale of 1:25 000. Using those experiences, in the years 1955 and 1956 the district of Mrągowo was mapped under the guidance of K. Dziewoński, and the district of Bielsk Podlaski under the guidance of J. Kostrowicki. For the first time the work went farther than distinguishing main forms of land use, as was the case in earlier studies. Their contents was also greatly extended. Within arable land, colours were used to mark individual groups of crops, denoted as cereal, root, fodder, industrial and horticultural crops, black signs were used to denote crop rotation periods (one, two, three... years). Meadows and pastures were divided into: dry, flooded and boggy; land melioration facilities were marked. Six types of woodlands were distinguished: coniferous forests, mixed forests, deciduous forests, deciduous forests on periodically floooded habitats, mountain forests and monocultures together with a number of sub-types, and the age of trees was marked. An important feature of this method was, in the case of arable land, that it did not treat each field separately but showed all fields as one whole within administrative unit (village, state farm, collective farm), for which the relative prevalence of separate crop groups was determined in the basis of statistical data.

The first attempt at a colour land use map were three printed samples from Mrągowo district. The *Detailed Land Use Map* (*samples*) together with a full legend in English was displayed at an International Geographical Seminar at Aligarh, India and at the 18th International Geographical Congress in Rio de Janeiro (Dziewoński 1956, Dziewoński and Kostrowicki 1956). This sample with F. Uhorczak's general map were recognized

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at the Congress as a remarkable achievement of Polish geography. This recognition was evidenced in the appointment of Poland's representative J. Kostrowicki to the Commission on World Land Use Survey of the International Geographical Union.

In 1956 a Laboratory of Agricultural Geography was set up at the Institute of Geography of the Polish Academy of Sciences. Under the guidance of J. Kostrowicki further work on the method for the elaboration of land use map was carried on in the laboratory. Methods of the field mapping, of collecting and elaborating data and the technique of map making were gradually changed, improved and enriched with new detailed forms and experiences resulting from the browing number of studies carried out in different parts of Poland. In this field, the Laboratory of Agricultural Geography collaborated with the faculties of economic geography of Cracow's Jagiellonian University and Gdansk's Higher School of Pedagogy starting from 1970 with Gdańsk University (Jankowski 1972, 1975; Kostrowicki 1959). Studies on land use in towns were initially conducted at the Laboratory of Population and Settlement Geography and subseqently at the Laboratory of Spatial Development at Institute of Geography of the Polish Academy of Sciences (Rakowicz 1958, 1959; Rakowicz-Grocholska 1970, Grocholska 1974).

The first instruction for detailed land use survey appeared in 1959 (*Instrukcja*... 1959). In the introduction entitled Polish Land Use Survey, J. Kostrowicki wrote that up to the end of 1958 a survey was carried out in seventeen places of Poland, covering the area of 7580 sq. km. On the basis of those findings, the contents of the map was successively enlarged to provide a comprehensive presentation of land use. The map covered relations of ownership, the agrarian structure, agrotechnics, arable land use orientations, animal breeding, gardens, perenial crops, permanent grassland, woodland, waters, settlement, mining areas, industrial-agricultural areas, industrial, commercial, transport and communication areas, public utility and recreation areas, unproductive lands and special areas. The above listed main categories, additionally divided into sub-types and groups, indicate the richness of the new map's contents. A year later the 2nd revised edition of the instruction appeared, which did not feature major changes (*Instrukcja*... 1959/6), and to satisfy the demand for information abroad, an outline of the instruction was published in English (Kostrowicki 1960).

In 1959 the method together with a specially prepared 1:25 000 map of the village Nieborów was presented to participants in the Anglo-Polish Seminar which was held in Nieborów. The map printed in 16 colours was an example of the newest version of the method (Biegajło, Kowalczyk and Piskorz 1961; Kostrowicki 1961).

The year 1960 marked the opening of a new period. The laboratory, re-named the Department of Agricultural Geography, began to test the usefulness of the method abroad and improve it in the new conditions. Owing to enriched methods of determination of orientations of arable land utilization and representation of new elements on the map, which do not occur in Poland, the Polish method became more universal and applicable under other than Polish conditions.

The third, i.e. so far the latest edition of the instruction appeared in 1962 (*Instrukcja*... 1962). All the rules contained in the instruction have been formally preserved till now, only the key of symbols has been en-

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riched with new signs to denote phenomena encountered in successive field studies. Following this instruction, a preliminary sheet Chroberz was published at the scale of 1:25 000 in two language versions — Polish and English (*Detailed land...* 1964). It was printed in 16 colours as a model sheet of the Polish survey. The legend was compiled on the basis of a full 24-colour key of nearly 300 symbols enclosed with a successive English-language version of the instruction (Kostrowicki 1964). This key was also the basis for the elaboration of maps enclosed with papers published under the common title *Land utilization in East-Central Europe. Case Studies* (*Land utlilization...* 1965). This joint work of several geographers of socialist countries edited by J. Kostrowicki contained thirteen 1:25 000 and 1:50 000 land use maps of selected units, of which six were from Poland, five from Yugoslavia, two from Bulgaria, as well as three black-and-white maps from Hungary elaborated in a different method. The book and the Chroberz sheet aroused great interest at the 20th International Geographical Congress in London. The method of Polish detailed land use survey and the method of its cartographic presentation have been presented, discussed and positively appraised at many international conferences. Proofs of this are to be found in world cartographic literature.[1]

In the 1970s the interest in land use surveys, especially those employing traditional methods, began to subside. An example of introducing new methods may be the analysis and interpretation of land use patterns in Warsaw performed by J. Grocholska with the use of representative samples (Grocholska 1974, 1975). The authores also investigates transformations in the spatial structure of land use throughout Poland (Grocholska 1980). Regrettably, her papers are not illustrated with cartographic material.

The Department of Agricultural Geography — a methodological centre of land use studies — completed its task successfully when it elaborated well-tested and recognized methods of mapping and graphic representation of survey results on maps. However, the execution of a survey of the whole territory of Poland was too much for the personnel and financial capacity of a research institution. Field work was abandoned for the sake of indoor work. Another attempt was then launched at elaborating a new general map. Working scale was set at 1:100 000 and reproduction scale at 1:200 000. More information about the principles of elaboration of this map are to be found in the closing part of the present paper. A number of theoretical and methodological works analysing and reviewing Polish and world attainments in land use mapping were written at the department (Biegajło and Jankowski 1972; Jankowski 1972, 1975, 1977b; Kostrowicki 1970), and also all of the work of the Commission on World Land Use Survey of the International Geographical Union was appraised (Jankowski 1977a).

When the Department of Agricultural Geography was gradually switching over from land use problems to work in the field of typology of

[1] Ch. Board, Land Use Surveys. Principles and practice, in: *Land use and resources. Studies in applied geography*, London 1968, pp. 24–41; A. Christofoletti, Land utilization, methods and problems of research (the review), *Sociologia* (São Paulo), 26, 1964, 4; A. Remy, Les travaux polonais sur l'utilisation du sol, *Études Rurales*, 12, 1964, pp. 134–136; M. Shafi, Land use planning, land classification and land capability. Methods and techniques, *The Geographer*, 16, 1969, pp. 1–8; L.D. Stamp, Land use studies in Eastern Europe, *Geographical Review* 54, 1964, 1, pp. 115–116; L. Symons, *Agricultural geography*, New York-London 1968, p. 283.

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agriculture, the Remote Sensing Centre (OPOLiS) was set up at the Institute of Geodesy and Cartography in 1975. Employing advanced remote sensing methods, in 1978 the Centre launched work on elaborating a land use map on the basis of Landsat MSS satellite images and photos taken in June 1978 by Polish cosmonaut M. Hermaszewski. The map was published in 1980 at the scale of 1:500 000 (*Polska...* 1980). This latest of Polish attainments, a result of employing advanced techniques, is not free from defects and arouses controversial opinions among specialits.

For reasons of space, the advantages and disadvantages of traditional and advanced surveys will not be discussed here in more detail. It is impossible to state unequivocally which of them are better. However, it seems evident that the future belongs to advanced study techniques, which will regrettably sever geographers even more from their fundamental fieldwork.

## INTERNATIONAL COOPERATION

The year 1960 marked the opening of a new period in Polish land use studies, a period of cooperation with foreign centres. It started with an international conference held in Warsaw from May 30 till June 8, with the participation of geographers from seven East-Central European countries — Bulgaria, Czechoslovakia, the GDR, Hungary, Poland, the Soviet Union, Yugoslavia, and a representative of the USA (*Land utilization...* 1962). Cooperation chiefly took the form of an exchange of research teams, which mapped selected areas. The first was September 1960 trip to Bulgaria, where in collaboration with local geographers studies were conducted in three localities of Bulgaria (*Land utilization...* 1965). Starting from 1962 the Department of Agricultural Geography conducted regular research in selected areas of Bulgaria, Czechoslovakia, Hungary, Rumania and Yugoslavia. Polish methods were used by Czechoslovak, Hungarian and Yugoslav geographers. Czechoslovaks elaborated a 1:50 000 land use map of the Kosice region and a 1:25 000 map of the village of Krâsna on the Hornad River. The centre in Ljubljana, Yugoslavia, used the Polish method for the mapping of selected units in Slovenia and Herzegovina; maps on some of them were printed in Poland and in the GDR by the Institut fur Agrarökonomik der Martin-Luther-Universität in Halle. Attempts at field surveys with the use of the Polish method were made at the Belgrade University. Also American geographer P.B. Alexander employed the Polish method for land use studies in karst areas of Yugoslavia.[2] In Hungary G. Enyedi publised a 1:25 000 map of the villages of Kerecsend and Maklar. W. Biegajło successfully tested the method in the area of Provence, France. The result of his work was a map of the commune of Banon printed in a black-and-white version as an enclosure to papers (Biegajlo 1965, 1966).

A successsive stage of international cooperation was the 2nd conference in Budapest (1964). In consequence of this cooperation, a Regional Subcommission for East-Central Europe was set up within the Commission for World Land Use Survey, with J. Kostrowicki as head (Kostrowicki 1965, 1968). Those ties between geographers of socialist countries were

[2] P.M. Alexsander, *Land utilization in the karst region of Zgornja Pivka, Yugoslavia*, University of Oregon, Dept. of Geography, 1964, p. 227.

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evidenced in the collection of papers from the Budapest conference published in Hungary. Enclosed with the papers were colour maps elaborated in Poland and printed in Czechoslovakia (*Land utilization...* 1967).

The findings of studies conducted by Polish teams abroad were published in fascicles of *Dokumentacja Geograficzna* (*Użytkowanie...* 1966, 1967, 1969). For reasons of economy, the land use maps enclosed with the findings were printed in black, which largely impoverished their contents and legibility in comparison with colour maps. A full bibliography of works on land utilization written till 1967 in Poland and other socialist countries was prepared by Kostrowicki and Tyszkiewicz (1968).

Within the series of annual conferences devoted to various specializations of cartography organized by Hungarian cartographers, a conference on land use maps was held in 1968 (*International...* 1970; Szczęsny 1970). An exhibition of maps which accompanied the conference provided a review of methodological and technical attainments and capacities of this branch of thematic cartography. Poland made a meaningful contribution to this exhibition.

Alongside members of the subcommission, guest cartographers and geographers from Norway, the FRG and Italy were invited to take part in the third land use conference (Kostrowicki 1970c; *Land utilization...* 1975). Participants in the conference recognized the usefulness of land use survey for typological work, which had been included in the activity of the subcommission. This fact was reflected in the new name Subcommission on Land Use and Agricultural Typology.

Work on the *Land Use Map of Europe* (*EULUSMAP*), published in 1980 at the scale of 1:2 500 000 was an example, unique in its kind, of international cooperation of geographers and cartographers from European countries, among them the author of the present paper on the Polish side (*Land use... 1980*). The project was initiated and subsequently supervised by Hungarian cartographer E. Csati, who was co-ordinator and editor-in-chief of the map. It was owing to his perseverance and energy that this giant task was successfully completed.

## POLAND'S GENERAL LAND UTILIZATION MAP IN 1 000 000 SCALE

The conception of this map, mentioned earlier in the paper, underwent a number of changes. Sheets of a 1:100 000 topographical map were used as the basis. Copies of individual land use categories were photoreduced from this scale to the scale 1:300 000. After a number of samples produced at various scales, it was decided that the map would be published at the scale of 1:100 000. Printed were five maps of main land use categories (waters, meadows and pastures, forests, arable land, settlement) and despite the 100-times surface reduction and the fact that montage was done twice, comprehensive maps were published: at first ten two-element sets, two three-element sets, two four-element sets and, finally, a map of all the five land use categories. The negative of arable land was additionally used for printing a map of the remaining four land use categories in brown; the area of arable land was left white to make possible the marking on it of other elements e.g. sown areas, soils, etc. The total of 22 maps together with administrative division on tracing paper were published. The printing of those maps was completed in 1957, and a historical and methodological commentary by F. Uhorczak appeared in 1969 (Uhorczak 1969).

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*Poland's General Land Utilization Map* has a number of unquestionable advantages, which are a result of the method used in its elaboration. At this scale and for all of Poland's territory, it was the first map which provided such a detailed image of rivers, meadows and pastures, forests, arable land and settlements with their great regional differentiation, free from distortions resulting from generalization. With the exception of built-up areas, all the elements of the map were shown in equal-area relation. In order to preserve the character in settlements in the process of mechanical reduction, 50 m equidistant from every building marked on the 1:100 000 map was applied. This provided for preserving the detailed content of the topographic map reaching 1 ha, which at this scale can be represented as a 0.1 mm-side square, i.e. one visible to the naked eye. The five maps of individual land use categories were displayed at the cartographic exhibition during the Geographical Congress in Rio de Janeiro. They were recognized as an achievement of Polish cartography.

## 1:25 000 DETAILED LAND USE SURVEY

The rich contents of the Polish detailed land use map in its full-colour version makes it stand out among other maps of this kind. Here is a brief description of the technique of field work and the method of cartographic presentation of materials collected during the survey. The framework contents of the map is defined by six main land use categories: agricultural land, forests, waters, settlement and associated non-agricultural land, unproductive land, special territories. Primary colours were adopted for each of the categories; colour shades indicate crops within arable land, tree species in forests, etc. The map also shows the form, orientation and intensity of land use. The ranges of individual land use categories are marked on the 1:25 000 map during fieldwork. Aerial photos, cadastral maps, management plans, etc. serve as supplementary materials. Every land use category is further examined within the limits of basic administrative and property units, ie. villages, state farms or cooperative farms, the borders of which are transferred on the base map from materials obtained from regional geodesy departments.

Agricultural land is divided into arable land, perennial crops and permanent grassland. The whole surface of arable land is distinguished and the prevalence of crops within groups is computed from statistical data for the given unit. The share of individual groups of crops (extractive, intensifying, structure-forming) in the total sown area is marked on the map with the use of a kind of a structural cartogram. The per cent share of groups is shown in four classes over 20, 30, 40, and 60 per cent, in the form of stripes of respective width of 1, 2, 4, and 6 mm. Shades of brown, the colour adopted for arable land, were used to show prevalent crops in groups. The method consisted in simply filling in an appropriate band with an appropriate colour. The reason for not distinguishing individual fields was to prevent the map from getting outdated fast in consequence of annual crop rotation in one field. As many years of the Department's work have shown, the orientation in the utilization of arable land, which can be learnt from structural cartogram, changes at a much slower pace. Apart from land use orientation, the map provides information about the intensity of animal breeding in the given unit, the crop rotation system, the degree of subdivision of land and fragmentation of farms.

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As the instruction remained the same, no changes were formally introduced to the technique of survey data elaboration. However, a new method of defining orientations in arable land utilization was introduced at the Department of Agricultural Geography. The marking of per cent share of groups and crops was abandoned for the sake of the method known as successive quotients. The method consists in determining the weight of individual crops by means of the proportion between them. On the map the orientations are shown with the use of a method similar to the structural cartogram. The basic stripe is taken to denote the total $\frac{6}{6}$ of arable land, and proportions between groups are shown as parts of the stripe, e.g. extractive $\frac{2}{6}$, intensifying $\frac{\text{[illegible]}}{6}$, structure-forming $\frac{1}{6}$ (Jankowski 1975; Jankowski and Kulikowski 1973).

In perennial crops the prevalent species of trees and shrubs are marked, and in orchards the age of trees is additionally shown.

Types of grassland are differentiated with yellow and orange shades. Appriopriate symbols are used to denote the manner of utilization (moving, grazing) and the condition of development.

Green shades indicate the species of trees in forests. Also the age of trees and form of economic activity are marked.

Waters (blue) are mainly differentiated by orientations in utilization and a biological (fishing) classification.

Built-up areas are divided into: residential (vermillon), industrial, mining, agricultural-industrial, commercial, communication (various shades of purple), public utilities (green), recreational (vermillon and yellow), other built-up areas (vermillon).

Unproductive land is differentiated by origin (natural and artificial) and type. Together with special areas, they are shown in grey.

It is owing to the exceptionally great share of fieldwork in the Polish survey that the map is so packed with details, verging on the limits of its capacity. At the same time, it supplies a great deal of information, which taken together provides an excellent basis for an analysis of the area, the condition of land use and rational land management.

## 1:200 000 SIMPLIFIED LAND UTILIZATION MAP

Having elaborated the method for a detailed survey, which, despite its many advantages, consumes a lot of time and money, the Department of Agricultural Geography launched an attempt at elaborating a method for a new general map. Although also in this case a 1:100 000 topographic map was taken for base map, the new work was to be completely different from Uhorczak's map. Reproduction scale was set at 1:200 000. The principle was adopted in the preparation of source material that most of the work would be done indoors, with maximum utilization of topographic maps, aerial photos and statistical materials, whereas fieldwork would be reduced to a minimum.

As concerns the plotting of land use categories and the grouping of crops, the principles applied in this map were the same as in the detailed map. Naturally, it was subject to both quantitative and qualitative generalization. The basic units studied were the commune, state or co-operative farm with area over 200 ha (Hauzer 1968; Kostrowicki and Kulikowski 1971). The method of successive quotients was used for marking crop combinations. The orientations are indicated on the map following the

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above presented principles, in reference to the basic units adopted for the general survey. Unlike on the detailed map, tree stands of forests are not shown in management sections, but in complexes with prevalent species determined on the basis of forest management plans. An area of some 60 000 sq. km. was experimentally covered on unpublished 1:100 000 maps. The map was designed as basic material for voivodship-level planning bodies. In order to avoid high printing cost, additionally elaborated was a version of the map which permitted printing in six colours, differentiating the main land use categories, and a black-and-white version (Jankowski and Kulikowski 1973; *Przeglądowa...* 1971).

Like in the case of the detailed map, the work stopped at an elaboration of the method and the printing of a sample sheet in the two above described versions. Although the usefulness of the detailed and the general surveys for not only scientific, but also practical purposes was frequently stressed, no competent person was able to appoint a special team to conduct this project. Completely different from the above desciribed principles as it was, a 1:500 000 general map of Poland elaborated from satellite images did appear. Regardless of its form, this map proves that the interest in the problems of land use mapping continues.

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# DOT LAND USE MAP OF POLAND

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The first large scale studies on the utlilization of land conducted in Britain in the 1930s gave rise to a vigoruos development of research into land use. In time, particularly after World War II, this research started to develop even more rapidly to become one of the preoccupations of the IGU, which set up the World Land Use Survey Commission in 1949.

As studies on land use were launched, an equally important problem emerged, which remains topical until the present day, namely the problem of cartographic representation of the findings of those studies, the problem of selection of cartographic methods (Jankowski 1977).

The method best suited for the presentation of such spatially occurring phenomena as the elements of land utilization is the areal (chorochromatic) method, described as a method of natural areas in which the occurrence of a phenomenon delineates boundaries of units, the range of phenomena being mutually exclusive (Ratajski 1973). This is the method used in the vast majority of land use maps, both at large and smaller scales. Maps elaborated on a topographic base, using the method of field mapping or maps using the interpretation of aerial photos or satellite images, provide a topographically reliable picture of individual land use forms or categories. Examples of the application of the areal method are land use maps of the two British surveys (1:63 360 and 1:25 000),[1] Italian maps (1:200 000),[2] Japanese maps (1:800 000),[3] a map of Austria (1:1 000 000),[4] and a map of New Zealand (1:3 200 000).[5]

Included in this group are also Polish maps from the inter-war years such as the 1:75 000 *Economy, Settlement and Shepherding Map of Tatra Mts.* by Hołub-Pacewiczowa (1931), the 1:500 000 *Land Use Map of Western Polesie* by Rühle (1930), the 1:500 000 *Distribution of Land Use Categories* (in Tatra Foothills) by Leszczycki (1938), and contemporary maps: Uhorczak's 1:1 000 000 Poland's *General Land Utilization Map* (1969) and Ciołkosz's 1:500 000 *Poland — Land Use* [6] elaborated from satellite images.

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[1] Cf. W. Jankowski, Drugie brytyjskie zdjęcie użytkowania ziemi (The second British land use survey), *Przegląd Geograficzny*, 42, 1970, 4, 757–761.

[2] *Carte della utilizzazione del suolo d'Italia, 1:200 000*, Touring Club Italiano, Milano 1959.

[3] *Japan Land Use, 1:800 000*, Tokyo 1947.

[4] Vorherrschende Landnutzung, 1:1 000 000, in *Atlas der Republik Österreich*, 1 Lieferung, Freytag Bernd und Artaria, Wien 1961.

[5] Land Utilization, 1:3 200 000, in: *A Descriptive Atlas of New Zealand*, P.E. Owen, Wellington 1960, p. 21.

[6] Map elaborated in the Institute of Geodesy and Cartography in Warsaw under the management of A. Ciołkosz.

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A different result is obtained when the areal method is combined with some other method, as is the case with land use maps elaborated by the Department of Agricultural Geography of the Polish Academy of Sciences Institute of Geography.[7] In those maps the areal method was combined with the 'structural choropleth method', which presents the share of individual crops within the range of arable land (Jankowski 1972).

Other methods used in land use maps are „code methods", in which individual land use categories are denoted by a figure or letter code placed within the area covered by the category.[8] Considering the legibility and aesthetic qualities of a map, those methods should only be used at working stages, when the characteristics of the distinguished area are recorded.

Over the recent years cartography has seen a tendency to use quantitative methods for the representation of natural phenomena, including phenomena from the sphere of land use. One of those methods deserves special mention. It is the dot method, which provides not only a statistical picture of a phenomenon, but also a picture of its spatial distribution (Burgomejster and Pasławski 1976).

First applied in the 1860s, to represent population phenomena (Hargreawes 1961), in time the dot method has grown to be widely used to present different kinds of phenomena (e.g., agricultural production, animal breeding)[9] and for the presentation of phenomena with an areal distribution (e.g., sown areas).[10] This method is primarily employed in small-scale maps, particularly atlas maps.

The most widespread is the classical form of dot map, where the weight of a phenomenon expressed in absolute values is shown in the form of a dot symbol. On small-scale maps, where the weight of a dot is relatively high, auxiliary symbols are sometimes used to present the phenomenon in more detail. Those symbols have different sizes and shapes, and their weight is lower than the weight of a dot and falls within the limits of some interval.[11]

In the 1950s percentage dot maps appeared (Mackay 1953). One dot represents an accepted percentage of the phenomenon and, regardless of the value of the presented phenomenon, each of a group of percentage dot maps has an identical number of dots 100, 1000 or 10 000.[12]

The different graphic forms applied do not change the essence of the dot method. Shapes of point symbols and their colours may vary, particularly on maps which present a number of homogeneous phenomena, such as kinds of crops, where symbols of individual crops often differ in weight, or different phenomena such as, for instance, population and arable land.[13]

[7] W. Jankowski, R. Kulikowski, Polska mapa użytkowania ziemi w skali 1:200 000 (Land use map of Poland, 1:200 000), *Polski Przegląd Kartograficzny* 5, 1973, 3, 111–115.

[8] Cf. W. Jankowski, Metody kartograficzne ..., 1977, Fig. 6.

[9] In: *The Atlas of Britain and Northern Ireland*, Clarendon Press, Oxford 1963; *Powszechny Atlas Świata*, PPWK, Warszawa 1973; *Oxford Economic Atlas of the World*, Oxford University Press, 1972.

[10] In: *The Atlas of Britain and Northern Ireland*, Clarendon Press, Oxford 1963; *Atlas Narodna Republika Bylgariya*, Sofia 1973.

[11] In: *Atlas selskogo khozyaystva SSSR*, GUGK, Moskwa 1960.

[12] In: *The National Atlas of Canada*, Surveys and Mapping Branch. Ottawa, F.A. 1970, F.B. 1972.

[13] W.W. Olsson, Wirtschaftskarte von Europa, Stockholm 1953, in: *Atlas över Sverige*. Svenska Sällskapet for Antropologi och Geografi, 1953; *Atlas over Skargards — Finland*, Nordenskiold — Samfundet, Helsingfors 1960.

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In the elaboration of dot maps which present phenomena with areal distribution, the size of the symbol (dot) is often at the scale of the map (Kolb 1940). However, this is not a necessary condition, and in the case of phenomena of greater areal range such presentation is not recommended (Porvin 1977), as it may lead to the coalescence of dots, which eliminates one of the merits of the map, namely quantitative information (Imhof 1972; Robinson, Sale and Morrison 1978). This difficulty may be overcome by way of using, 'map-scale symbols' in the shape of squares, which may easily be separated by thin lines. When the squares are distributed regularly, they form a dense grid.[14]

Jenks's map is an interesting example of a dot map. Jenks compared the elaboration of this map to the technique known in painting as Pointillism. He presents twelve crops using dots of twelve colours. As a result, a greater concentration of one crop gives a clear stain of one colour; a dispersion and combination of crops give resultant colours of different hues depending on the kind (colour of dots) and density of particular crops (Jenks 1953).

The above described variants of the dot method were only employed for the presentation of selected phenomena occurring over an area, such as kinds of crops or individual land use categories. Hence dots occurring individually or in bigger or smaller concentrations never represented the whole area of a map, as is the case on „areal maps".

The present paper is a methodological attempt at elaborating a land use map of Poland by means of the dot method. This map was made on the basis of statistical data of the September 1977 agricultural census by rural districts and Uhorczak's 1:1 000 000 *Poland's General Land Utilization Map* (1969).

Uhorczak's land use map was elaborated on the basis of 1:100 000 topographic maps, whose content embraced the main land use forms. Like many maps of this type, elaborated with the use of the areal method, it provided a topographic picture of five land use categories: forests, meadows and pastures, arable land, waters, and settlements. When reducing the scale for the first four categories photographic generalization only was used, hence the ratio of areas under individual land use categories remained unchanged. The lifth element — settlements, was represented with the use of equidistant method, with $r = 0.5$ mm at the scale of the source map, which delineated a 50 m boundary around buildings, thus exaggerating somewhat the built-up area.

This study is not the first of this kind conducted at Maria Curie-Sklodowska University. Already earlier two 1:1 000 000 dot maps of some land use categories were experimentally elaborated. They were a map of forests (Fig. 1) and a map of meadows and pastures (Fig. 2). They were elaborated on the basis of the General Land Use Map of Poland and statistical material assembled by poviats in the old administrative division. The dots, 100 ha in weight, were distributed topographically. Owing to the size of the dots, which were 0.7 mm in diameter, the cartometric character of the map was preserved — it was possible to count the dots.

The maps provided a topographical and statistical picture which was reliable from the viewpoint of the adopted principles. However, they were

[14] In: *Suomen Kartarto-Atlas of Find*, Kustannusosakeyhtio Otava, Helsinki 1960.

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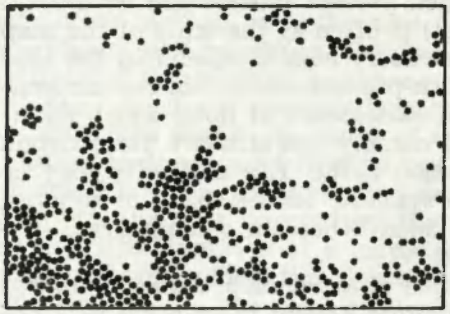

Fig.1

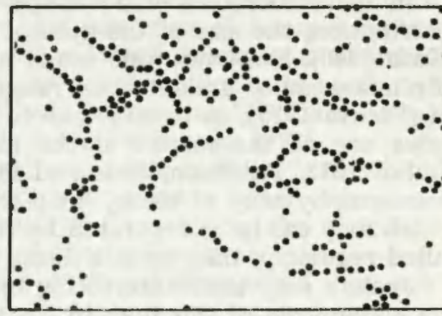

Fig.2

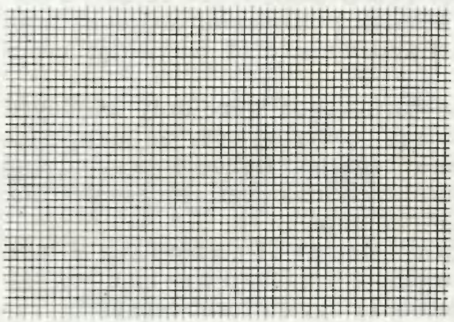

Fig.3

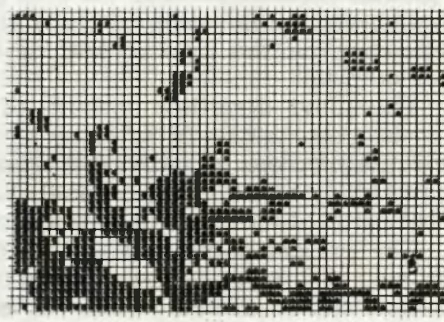

Fig.4

not free from certain shortcomings. Each of the maps was elaborated separately and therefore, after they were overlaid, they were not fully consistent as regards the range of individual adjacent land use categories. The other shortcoming was due to the fact that the density of dots plotted in the area of the given land use category in accordance with quantity statistics was not uniform, the effect of which was misleading. In view of those shortcomings the authoress abandoned her initial intention of elaborating a third dot map of arable land.

In order to eliminate those faults and finally produce a land use map which would represent statistical data and cover all of the country's territory without exception, it was decided that a land use map would be made adopting the dot method and a regular distribution of dots in topographical area (Salishchev 1977). With an eye to that, a grid of 1 mm-side squares was made at the scale of the map, i.e. 1:1 000 000 (Fig. 3). The area of each square stands for 100 ha, i.e. the intended weight of the dot. The grid was overlaid on the map of Poland so that $\lambda = 19°$ meridian converged with one of the vertical lines of the grid, and one of its horizontal lines passed through the point of intersection of 19° meridian and $\varphi = 52°$ parallel. Voivodship borders were plotted on the grid overlaid in this way. The graphic representation of the borders was simplified — they were plotted on the lines of the grid; the area of voivodships was plotted exact to a square kilometer (100 ha, full squares of the grid are included in voivodship areas). Borders of rural districts were treated as auxiliary, working representations, hence their outlines were not changed. Considering the weight of the dot and the size of areas occupied by land use categories

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in individual rural districts, a graphic simplification of rural district borders and the striving to preserve the areas of rural districts, as was the case with voivodships, would burden the map with excessive detail, which was both unimportant and unfeasible at the scale of the map.

The following four land use categories were plotted in four colours of dots over this base:

| | |
|---|---|
| arable land (and orchards) | — yellow |
| meadows and pastures | — light green |
| forests | — dark green |
| others (built-up areas, waters, roads, unproductive land) | — brown |

The dots were plotted regularly in meshes of the grid within boundaries of land use categories; their number corresponded to statistical data for rural districts (Fig. 4).

The author tried to keep the size of the dot not bigger than $\varnothing = 0.75$ mm, which resulted in 44.2 per cent coverage (44.2 $mm^2$ per 1 $cm^2$). The size of the dot was determined empirically, so that concentrations of one land use category dots made up colour stains marking the topographical range (Jenks 1953), and it was possible to count the dots (Burgomejster and Pasławski 1976; Provin 1977).

Certain problems emerged during the elaboration of the map. They resulted from the fact that the picture of land use provided by the *Polish General Land Use Map* was not up to date. Since the time the 1:100 000 source maps were elaborated, both the ranges of individual land use categories and the sizes of their area had undergone changes, to say nothing of the fact that, due to generalization, a topographic map ignores small patches of forests, meadows, etc. The authoress tried to overcome this difficulty by way of using newer cartographic material. However, the unavoidable departures from geographic location do not, the authoress believes, diminish the usefulness of the elaborated map.

The final result of the work was a dot *land use map* with full coverage of Poland's territory (Fig. 5).[15] Apart from that, it was also possible to print four extra maps, namely four dot maps of individual land use categories: arable land (Fig. 6), forests (Fig. 7), meadows and pastures (Fig. 8), and 'others' (Fig. 9).

By way of combining individual land use categories, it is possible to obtain: a land use map — arable land + meadows and pastures + forests, without the 'other' elements. Although on this last map white spots do not provide quantity information, it does seem purposeful to make such a map, as the label 'others' comprises genetically diverse phenomena such as settlements, roads, waters, etc. Owing to that, it will be possible to plot some of those phenomena, e.g. towns and bigger settlements.

Here are the final conclusions of the work:

1. The general land use map of Poland made with the use of the dot method provides an image of four categories of land use in Poland which is reliable both statistically and as regards the topographic location.

2. The manner of dot distribution illustrates the topographic distribution of the phenomenon and provides for their cartometric quality; it is easier to count the dots due to the regularity of the picture.

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[15] Figures 5–9 are enclosed separately under the back cover.

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3. The map provides for a simple and easy computation of statistical values for freely selected units of area, independently from administrative borders. Those freely selected units may be regular shapes, natural physiographic units, or others. Transformation of this type is relatively easy and exact, and the map may serve as base material for various further studies.

4. Owing to the purpose that the map is to serve, i.e. the transformation of content onto other area units, the possible departures from topographic location are unimportant. Those units may even be smaller than the primary unit — the average rural district; location errors can be ignored.

A manual elaboration of such maps is extremely labour-consuming, it would be advisable to elaborate them with the use of computer assisted cartography. However, one problem must be resolved before that is done: a method must be elaborated for the combination of census information and information about the location of a phenomenon derived from the map.

Land use maps elaborated on the basis of satellite images have recently appeared. However, due to the method of elaborating such maps and the properties of input material, they are not statistically reliable, particularly as concerns areas where land use categories are largely comminuted.

A number of larger-scale land use maps eleborated, like the presented map, on the basis of a regular grid of squares, were also brought out in the 1970s (Kaulfuss 1973). Reproduced in colour, they provide a picture similar to a regularly arranged dot map.[16] When printed in a single colour, the picture is poorly legible and schematic (Kaulfuss 1973, Table 4). A symbol represents a land use category which prevails in the given area unit, without providing quantity information.

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# THE TYPES OF AGRICULTURE MAP OF EUROPE

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The type of agriculture map is neither a land use map nor a map of crop or/and animal distribution or combination. It is a synthetic map representing all significant characteristics or attributes of agriculture: social, operational, productive and structural expressed in a quantitative way and put together by computer.

The elaboration of a map of world types of agriculture was one of the objectives of the Commission on Agricultural Typology of the International Geographical Union. Although the method was elaborated (Kostrowicki 1972a), tested by numerous case studies in a number of countries (see Reeds 1973; Vanzetti 1972, 1975; Kostrowicki and Tyszkiewicz, eds 1970b, 1919 and others) and after many discussions accepted as workable, for many reasons the whole work was delayed and the map was never attempted.

What resulted from those studies was a number of types of agriculture maps of various countries, mostly in black and white. Those maps, however, because the method of types identification evolved and in spite of some attempts (Kostrowicki 1975) a common legend was never established, could hardly be comparable.

The idea, however, has not been abandoned. Based on the cooperation of a number of European geographers, the first draft of the types of agriculture map of Europe drawn by W. Jankowski was elaborated in 1980 and presented to the 24th International Geographical Congress in Tokyo.

In order to elaborate that map, several methodological problems had to be solved and tackled in advance.

For those who are not familiar with the principles and methods of agricultural typology they are briefly summarized below. More detailed information can be found in several publications (Kostrowicki 1964, 1966a, 1966b, 1970, 1972a, 1972b, 1973, 1974, 1976, 1977, 1978, 1980; Kostrowicki and Tyszkiewicz 1970a).

Agricultural typology is based on 27 variables representing various social, operational, production and structural characteristics or attributes of agriculture (Table 1). Those variables, expressed in different units and measures are normalized, based on world ranges of those variables. Reduced to five classes (Table 2), they are presented in codes. Similar codes worked out for investigated units are compared with model codes established in advance and based on a study of over 1000 cases, covering most of the world. When the investigated units do not differ from one or more of the model codes by more than the arbitrarily adopted maximum, they are recognized as the same types as represented by those model codes.

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TABLE 1. Variables used in agricultural typology

*A. Social attributes*

1. Percentage rate of land held in common in the total agricultural land (arable land including fallow+perennial crop+permanent grassland).
2. Percentage rate of land in labour and share tenancy (share cropping) in the total agricultural land.
3. Percentage rate of land owned by private persons (irrespective of the land tenure system) in the total agricultural land.
4. Percentage rate of land operated by the consciously planned collective or state enterprises in the total agricultural land.
5. Number of people actively employed in agriculture per 1 agricultural holding.
6. Amount of agricultural land in hectares per 1 agricultural holding.
7. Amount of agricultural gross production in conventional units (see appendix) per 1 agricultural holding.

*B. Operational attributes*

8. Number of people actively employed in agriculture per 100 hectares of agricultural land.
9. Number of draugh animals (horses, mules, asses, oxen, buffaloes — if used in agricultural work) in conventional draught units (see appendix) per 100 hectares of cultivated land (arable land without fallow+perennial crops+cultivated grassland without uncultivated meadows and pastures).
10. Number of tractors and other self-propelling machinery in HP per 100 hectares of cultivated land.
11. Amount of chemical fertilizers in pure content (NPK) per 1 hectare of cultivated land.
12. Percentage rate of irrigated land in the total cultivated land.
13. Percentage rate of harvested land in the total arable land (including follow).
14. Number of farm animals in conventional (large) animal units (see appendix) per 100 hectares of agricultural land.

*C. Production attributes*

15. Gross agricultural production in conventional units per 1 hectare of agricultural land.
16. Gross agricultural production in conventional units per 1 hectare of cultivated land.
17. Gross agricultural production in conventional units per 1 person actively employed in agriculture.
18. Commercial (delivered off farm) agricultural production in conventional units per 1 person actively employed in agriculture.
19. Percentage rate of commercial (delivered off farm) agricultural production in gross agricultural production.
20. Commercial agricultural production in conventional units per 1 hectare of agricultural land.
21. Degree of specialization in commercial agricultural production (see appendix).

*D. Structural attributes*

22. Percentage rate of perennial (trees, shrubs, vines) and semi-perennial (covering land without rotation for some years such as hops, cotton, sugar cane etc.) crops in the total agricultural land.

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23. Percentage rate of permanent grassland (including leys within field-grass system and current fallow if used for grazing) in the total agricultural land.
24. Percentage of land under food crops (food grains, tuber, root and bulb crops, vegetables and fruits) in the total agricultural land.
25. Percentage rate of animal products in gross agricultural production.
26. Percentage rate of animal products in commercial agricultural production.
27. Percentage rate of industrial crops (such as fiber, oil, sugar crops, tobacco etc.) in gross agricultural production.

TABLE 2. Classes of world ranges of individual attributes

| No. of the variable | Classes 1 very low | 2 low | 3 medium | 4 high | 5 very high |
|---|---|---|---|---|---|
| 1 | – 20 | 20–40 | 40–60 | 60–80 | 80– |
| 2 | – 20 | 20–40 | 40–60 | 60–80 | 80– |
| 3 | – 20 | 20–40 | 40–60 | 60–80 | 80– |
| 4 | – 20 | 20–40 | 40–60 | 60–80 | 80– |
| 5 | – 2 | 2–8 | 8–50 | 50–200 | 200– |
| 6 | – 5 | 5–20 | 20–100 | 100–1000 | 1000– |
| 7 | –100 | 100–1000 | 1000–10 000 | 10 000–100 000 | 100 000– |
| 8 | – 3 | 3–15 | 15–40 | 40–150 | 150– |
| 9 | – 2 | 2–8 | 8–15 | 15–30 | 30– |
| 10 | – 6 | 6–15 | 15–35 | 35–90 | 90– |
| 11 | – 10 | 10–30 | 30–80 | 80–200 | 200– |
| 12 | – 10 | 10–25 | 25–50 | 50–80 | 80– |
| 13 | – 10 | 10–30 | 30–70 | 70–130 | 130– |
| 14 | – 10 | 10–30 | 30–80 | 80–160 | 160– |
| 15 | – 5 | 5–20 | 20–45 | 45–100 | 100– |
| 16 | – 5 | 5–20 | 20–45 | 45–100 | 100– |
| 17 | – 40 | 40–100 | 100–250 | 250–800 | 800– |
| 18 | – 20 | 20–60 | 60–180 | 180–600 | 600– |
| 19 | – 20 | 20–40 | 40–60 | 60–80 | 80– |
| 20 | – 3 | 3–12 | 12–30 | 30–80 | 80– |
| 21 | – 0.1 | 0.1–0.2 | 0.2–0.4 | 0.4–0.8 | 0.8– |
| 22 | – 10 | 10–20 | 20–40 | 40–60 | 60– |
| 23 | – 20 | 20–40 | 40–60 | 60–80 | 80– |
| 24 | – 20 | 20–40 | 40–60 | 60–80 | 80– |
| 25 | – 20 | 20–40 | 40–60 | 60–80 | 80– |
| 26 | – 20 | 20–40 | 40–60 | 60–80 | 80– |
| 27 | – 20 | 20–40 | 40–60 | 60–80 | 80– |

As the whole system is open, new types based on the cases that deviate from the model-codes by more than that maximum are described in a similar way by codes.

Coming back to the map of Europe, 1:2.5 million scale has been adopted with possible reduction in the printed version.

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Taking into account that scale it has been decided that administrative units of the highest order or comparable agricultural regions are accepted as basic units.

The data for such units have been collected by three centres of study: a) in Paris for the Common Market countries by the group headed by J. Bonnamour and Ch. Gillette; b) in Moscow for the USSR by the group under the methodological guidance of A.N. Rakitnikov (Gorbunova and others, 1979); c) in Warsaw for the countries of East-Central Europe by the following research workers of the Institute of Geography and Spatial Organization, Polish Academy of Sciences: R. Szczęsny (Poland, GDR, Rumania, Austria, Switzerland, Finland), W. Tyszkiewicz (Czechoslovakia, Hungary, Yugoslavia), B. Gałczyńska (Bulgaria) and R. Kulikowski (Spain).

In addition, some material has been obtained from B. Cori and his group (for Italy), A.B. Tschudi (for Norway), U. Janson (for Sweden) and W. Stola (for Belgium). Most of the data collected are for the years between 1975–1980.

As the data for some countries (Portugal, Greece, Albania) have not been obtained to date and the data for other countries were computed not for the same period, the present map should be considered as a tentative one.

All codes for basic units of study were compared in Warsaw by means of a computer (for the programme see Kostrowicki 1980) with the model codes elaborated by the Commission.

The land use map of Europe elaborated by E. Csati (1980) and the maps from World Atlas of Agriculture edited by C. Vanzetti (1969), have been accepted as basic maps.

These maps were also used to eliminate non-agricultural lands which were then marked by neutral colours — black for cities and grey for other non-agricultural land. Agricultural types were then denoted on agricultural land without its any further subdivision.

Agricultural types were marked by various colours according to the following principle (see legend, Fig. 1).[1] The types of the first order differ from each other by main colours, the types of the second order — by shades of those colours, and those of the third order — by various symbols (stripes, dots, circles, squares, etc.).

Accordingly, it was decided that: Traditional extensive agriculture (E) was marked in yellow, Traditional intensive agriculture (T) — in green, Market oriented agriculture (M) — in blue, Socialized agriculture (S) — in red and Highly specialized livestock breeding (A) — in brown.

Out of the types of the first order, the first — Traditional extensive agriculture (E) — is almost non-existent in Europe, and the last — Specialized livestock breeding (A) could only be found on either some marginal land or does not cover sufficiently large areas to be marked on the map of the adopted scale.

As far as the types of the second order are concerned, most of the units fall upon the types already described in the scheme (Kostrowicki 1980), first of all upon the Traditional, small scale agriculture (Tm) marked in pale green, then Market oriented, small scale agriculture (Mm) — pale blue, less often Market oriented intensive crop agriculture (Mi) — navy blue, or Market oriented large-scale agriculture (M) — lilac blue,

[1] Figure 1 is enclosed separately under the back cover.

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then Socialized mixed agriculture (Sm) — vermillon and less common Socialized horticulture (Sh) — dark crimson, Extensive specialized crop agriculture (Sc) — crimson on white and Specialized industrial crop agriculture (Ss) — purple.

The only case of the new type of the second order has been described (by B. Gałczyńska) basing on the material from Southern Bulgarian mountains, which represents socialized agriculture combining intensive specialized crop agricuture in the valleys with extensive livestock grazing in the mountains. Later on a similar type of agriculture was identified in the Armenian SSR.

Many more new types of the third order were discovered and described on the basis of the material collected for the map. At the same time with more material available some codes, representing types already described, had to be revised.

Symbols adopted to differentiate the types of the third order are based on the following principles:

For types specializing in livestock breeding — vertical stripes; for those specialized in crop growing — horizontal stripes; for mixed agriculture with livestock breeding prevalent — diagonal stripes going from upper left to lower right; for mixed agriculture with crop growing prevalent — diagonal stripes going from upper right to lower left; for fully mixed agriculture — no stripes, and for other types — various other symbols.

Finally, the following types of agriculture have been presented on the map (codes: see Table 3).

TABLE 3. Model codes for agricultural types of Europe

| | | |
|---|---|---|
| Tiu | 1151112–4422454–3322321–214111 | |
| Tme | 1151121–3413133–2211211–123331 | new |
| Tmr | 1151211–4411244–2211211–114211 | = Tir |
| Tmh | 1251211–4511343–2411111–122341 | |
| Tmm | 1151222–3323143–3423321–123231 | |
| Tmc | 2241212–4422243–3423332–224221 | |
| Tmj | 1151111–4434244–3211223–214222 | new |
| Tmk | 1151112–4423144–4421233–122351 | new |
| Tmo | 1151111–3234142–4432122–123331 | new |
| Tma | 1151232–2223143–3433333–131341 | = Mmt |
| Mmm | 1151222–3255144–4444442–123231 | |
| Mmz | 1151122–1153243–2344423–141441 | new |
| Mma | 1151233–2154144–4444444–141451 | revised |
| Mmc | 1151222–4244242–4434443–213222 | |
| Mmr | 1151233–2154142–3354432–122221 | new |
| Mmn | 1151222–3155342–4445544–112213 | |
| Mmi | 1151222–3155355–5545553–212441 | new |
| Mmf | 1151112–3253242–4433542–323221 | new |
| Miv | 1151222–4145352–5534555–115111 | |
| Mim | 1151122–2154142–3345534–414111 | new |
| Mif | 1151222–4134241–4444545–415111 | |
| Mlm | 1151345–2154143–4455543–123232 | revised |
| Mlc | 1151244–2154441–4455542–114112 | |
| Mlh | 1151345–2154241–4445545–315111 | |

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| | | |
|---|---|---|
| **Mln** | 1151255–2155242–4455545–311114 | |
| Mec | 1151254–1152131–2255525–115111 | |
| **Mem** | 1151254–1152132–3355534–133331 | |
| Arr | 1151353–1100001–1022515–151551 | |
| **Aro** | 1115555–1100001–1034515–151551 | new |
| Sem | 1115443–3233132–2333321–133331 | |
| **Sec** | 1115443–3232231–2322422–124121 | |
| Smm | 1115555–2144143–3434432–132341 | |
| Sma | 1115555–2253142–2322424–143551 | new |
| Smd | 1115454–3155144–4444443–113351 | new |
| Smc | 1115555–3233242–3433432–223221 | |
| Smu | 1115555–3144243–3344534–114222 | new |
| Smi | 1115555–2154443–4455543–122222 | |
| Sme | 1115555–1141131–1332413–154441 | revised |
| **Smj** | 1115454–2154141–1332423–143221 | new |
| **Sgt** | 1115555–4444342–2312423–141233 | new |
| Sin | 1115555–4322143–4422222–224221 | new |
| **Sii** | 1115555–5422454–5522232–114111 | new |
| Shg | 1115545–5155551–5555555–115111 | |
| Shj | 1115454–3144341–3333534–313111 | new |
| Shf | 1115555–3133241–4444545–415111 | |
| **Shv** | 1115545–4154342–4434555–115111 | |
| **Scc** | 1115555–1143131–2234525–115111 | new |
| Ssc | 1115555–2154442–3434535–332114 | |

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**T** **Traditional intensive agriculture**[2]

Ti *Traditional, small scale, labour intensive crop agriculture*

Tiu Irrigated, medium productive, semi-subsistence to semi-commercial crop agriculture — transitional between Ti and Tm; found in limited territories only in Macedonia as a relict of an old traditional labour intensive agriculture.

Tm *Traditional small-scale, mixed agriculture*

Tmr (formerly Tir). Labour intensive, low productive, partly irrigated semi-subsistence mixed agriculture with some livestock breeding — transitional between T and E and Ti and Tm. Also in Macedonia.

Tme (new). Transitional, small-scale, low productive, semi-subsistence mixed agriculture.
Described (by W. Tyszkiewicz) on the basis of the material also from Macedonia.

Tmm Semi-subsistence to semi-commercial mixed agriculture. Poland, parts of Yugoslavia.

Tmj (new). Traditional, small-scale, labour intensive, low productive, semi-subsistence mixed agriculture with crop growing prevalent.

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[2] It should be taken into account that out of 27 attributes only a few, the most important or the most differentiating the given type from the other, could be used in name.

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Tmk (new). Traditional, labour intensive, medium productive, semi--subsistence mixed agriculture with livestock breeding prevalent. Mainly in Southern Poland, Yugoslavia, parts of Rumanian mountains.

Tmo (new). Traditional, medium intensive, medium productive, subsistence mixed agriculture with livestock breeding prevalent. Poland and Yugoslavia, representing mostly part-time farming.

Tma (formerly Mmt). Medium scale, semi-commercial, mixed agriculture with livestock breeding prevalent — transitional between Tm and Mm.
Mainly in the mountains: Austria, Norway, Finland, but also in the Central Massif in France, in Yugoslavia, Rumania and Poland.

**M Market oriented agriculture**

Mm *Small-scale mixed agriculture*

Mmm Small-scale mixed agriculture.
Western Poland, central part of the Federal Republic of Germany, north-eastern Austria, some parts of Northern Italy, Brittany, north-eastern France and central Belgium, some parts of southern Norway and Finland.

Mmz (new). Market-oriented, small scale, medium productive, mixed agriculture with livestock breeding prevalent. Mountains of southern France, Alps, Corsica and Sardinia.

Mma (revised). Market oriented, capital intensive, mixed agriculture specialized in livestock breeding.
Britain, Ireland, Normandy, parts of the Netherlands, parts of northern and southern Federal Republic of Germany, Denmark, parts of Norway and Finland.

Mmc Small scale mixed agriculture with crop growing prevalent. Some parts of Italy.

Mmr (new). Market oriented, capital intensive, mixed agriculture with crop growing prevalent.
Central, eastern and south-western France; parts of Italy.

Mmm Small-scale mixed agriculture, with industrial crop prevalent. With the scale adopted only in some parts of Italy and Austria.

Mmi (new). Market oriented, highly capital intensive, very productive, very commercial, mixed agriculture with livestock breeding prevalent.
Lombardy, northern Belgium, the Netherlands.

Mmf (new). Market oriented, small-scale, medium intensive mixed agriculture with crop growing prevalent including high proportion of perennial crops.
Most of central and southern Italy, Italian Riviera, Provence.

Mi *Small-scale intensive agriculture*

Mim (new). Market oriented, small-scale, capital intensive agriculture specialized in perennial crop growing.
Some parts of south-eastern Italy, southern parts of Sicily, parts of Provence and Languedoc.

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| | |
|---|---|
| Mif | Specialized fruit-tree growing, Transitional between Mi and Ms. Parts of Italy and southern France. |
| Ml | *Large-scale intensive agriculture* |
| Mlm | (revised, formerly Mml). Market oriented, large scale, highly productive mixed agriculture. Parts of the Paris Basin and western France. |
| Mlc | Large scale, irrigated, mixed crop agriculture Paris Basin. |
| **A** | **Highly specialized livestock breeding** |
| Ar | *Extensive commercial herding* |
| Arr | Market oriented livestock grazing. Large scale, extensive, very low productive, commercial, highly specialized reindeer breeding. Northern Finland. |
| Aro | Socialized livestock breeding. No codes available. Northern parts of the Russian Federal Republic; marked on the basis of the Agricultural Atlas of the USSR. |
| **S** | **Socialized agriculture** |
| Se | *Incipient (mixed, low intensive) socialized agriculture* |
| Sem | Incipient, mixed agriculture. Some parts of Rumania, Bulgaria and the USSR. |
| Sec | Incipient mixed agriculture with crop growing prevalent. Some parts of Rumania and the USSR. |
| Sm | *Socialized mixed agriculture* |
| Smm | Mixed agriculture Parts of the GDR, Czechoslovakia, Poland, Hungary, Rumania, Bulgaria and Yugoslavia, parts of the Estonian and Lithuanian SSR, western parts of the Byelorussian and Ukrainian SSR. |
| Sma | (new). Socialized, very large scale, medium intensive, low productive, mixed agriculture with livestock breeding prevalent. Most of the Northern part of the European USSR. |
| Smd | (new). Socialized large scale, very highly capital intensive, highly productive mixed agriculture with livestock breeding prevalent. Most of the German Democratic Republic, parts of Czechoslovakia, Hungary and Poland. |
| Smc | Mixed agriculture with crop growing prevalent. Parts of Rumania, Bulgaria, parts of the Ukrainian and Moldavian SSR, parts of the Middle Volga and North Caucasus regions. |
| Smu | (new). Socialized, very large scale, highly capital intensive, highly productive mixed agriculture with crop growing prevalent. Most of the Ukraine, Don and Kuban regions, parts of Rumania and Bulgaria. |
| Smi | Capital intensive, irrigated mixed agriculture. Some parts of eastern Rumania. |

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Sme (revised). Extensive livestock breeding with subsidiary crop growing
Along the Caspian Sea coast: the Daghestan and Kalmyk autonomous republics, Astrakhan and Chelabinsk provinces.

Smj (new). Socialized large-scale, very low labour and highly capital intensive, mixed agriculture with livestock breeding prevalent.
Macedonia.

Sg *(new). Socialized intensive, medium productive, dual purpose agriculture*

Sgt (new). Socialized, very large scale agriculture oriented toward intensive crop growing and extensive livestock breeding.
Bulgaria — southern mountain area (The Rhodope and Rila Mts), Armenian SSR.

Sn *Socialized horticulture*

Snj (new). Medium productive socialized horticulture, specialized in fruit and vegetable production.
Parts of southern Macedonia and Crimes.

Sc *Extensive, specialized grain-crop agriculture*

Scc Extensive specialized grain crop growing
South-eastern parts of the European USSR.

Se *Specialized industrial crop agriculture*

Ssc (new). Socialized, very large scale, capital intensive, medium to highly productive agriculture specialized in industrial and fruit crops.
Georgian and Azerbaijan Soviet Republics.

As one can see from the enclosed sample maps the individual units of study are marked either by one of the adopted colours and symbols or by two, three or even four belts of varying width. This is so because it was decided when distances between the code for a given unit and more than one model code are similar, to identify such a unit as being of transitional character between two or more types. To identify such transitional forms the technique of successive products was applied (Kostrowicki 1980; Tyszkiewicz 1980; Stola 1982).

As one can also notice from the map, more types are comprised in both the legend and the enclosed Table of model codes than have been listed above. This is due to the fact that some of the types that have been described from Europe earlier could not be identified on the basis of the material collected, either because they have disappeared or cover too small areas to be presented on the scale of the map.

On the other hand, most of the the newly described types have been discovered either in the Mediterranean countries or in Macedonia.

There are several reasons. First the model codes for world types were established on the basis of the material compiled some years earlier, whereas a considerable progress has afterwards taken place in the Mediterranean agriculture and particularly in Italy. As far as Macedonia is concerned, there are also two reasons; this is indeed a country in which along with modern socialized or private agriculture one may also encounter very antiquated forms of agriculture. On the other hand, in 1970, there

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were no other administrative units below the federal republic but communes (*obstina*) and obviously the smaller the units the more differentiated is the picture, particularly in a country so sharply differentiated from the point of view of both natural conditions and economic development (Tyszkiewicz 1980).

This leads to the whole problem of basic units. As mentioned above, it has been decided that the administrative units of the highest order shall be adopted as basic units for the map.

But, first, the size of the administrative units of the highest order in various European countries is very varied. In the USSR (*oblast*) they are much larger than elsewhere. As, however, the internal differentiation of the Great Russian Plain is not great, this does not distort much the reality, which is proved by the individual types pass usually from one to another through the intermediate mixed forms. The exception is the Caucasus and Crimea. Fortunately the data for northern Caucasus are available for various autonomous republics which are nor very large. The situation is worse with Transcaucasian republics. Particularly the Georgian and Azerbeijan republics are too large and too much differentiated internally to be treated as one unit each, even within the adopted scale.

The administrative units of Poland, GDR, Czechoslovakia, Hungary, Rumania, Bulgaria as well as of Finland, Sweden and Norway seem to be of the optimum size as far as both the scale of the map and their internal differentiation are concerned.

On the other hand, the data for the Common Market countries were computed for the EEC agricultural regions which, while not uniform in size, are in general too large. Belgium, the Netherlands, Denmark and Ireland are certainly too big to be treated as one unit each. Most of the agricultural regions of France, Italy, the Federal Republic of Germany or Britain are also too big for internal differentiation of agriculture to be sufficiently reflected. For Italy, however, it was possible to get additional data for *regioni,* i.e. for about one hundred units and for France for small agricultural regions which are too numerous (over 700). It has been possible however, on the basis of those small regions, to elaborate the codes for the departments, i.e. again for about one hundred units.

A special case is Yugoslavia. The data could be collected either for federal republics, most of which are both too large for the adopted scale and too much differentiated internally or for communes (*obstinas*) which are too small (about 700 for the whole of the country). Recently some kind of intermediate units (*zajednica*) have appeared in some republics. Respective data for Serbia as well as for Bosnia and Hercegovina have been completed, but until recently not for any other republic such material has been available.

Here an important methodological problem also arises that would be worth while investigating. How much and to what extent are the internal differentiations of agriculture presented, say, by small agricultural regions distorted when passing to larger units? Do agricultural types identified for larger units only generalize the picture based on smaller units or to they distort that picture forming types that do not exist in reality? As yet there is no answer to those questions. It seems that in the units that are less differentiated internally the type for a larger unit may be just such a generalization, while for the strongly differentiated units it may reflect no reality. There is a question whether some of the new types described

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on the basis of the material collected for the map would not disappear when passing to smaller units. The material for France, for which the typology was made at the same time for small agricultural regions, departments and EEC regions does not confirm that fear. The question could only be resolved by a special study for which the material for the units of various orders is collected and specially analysed.

What agro-geographical conclusions could be made from the presented map?

Because of a general progress in agricultural development and the expansion of socialized farming, traditional semi-subsistence or semi-commercial agriculture (T) has survived only in Poland, Yugoslavia, in both of which individual, private agriculture is passing to modern market oriented agriculture.

As some studies carried out in those countries confirm, some changes are also taking place within the traditional agriculture, in particular low commercial agriculture of part-time farmers reflected by the type Tmo is expanding tending to eliminate larger and larger areas from the market economy.

Also the traditional type Tma, which covered once quite extensive areas in northern Europe, is now limited mainly to the Scandinavian countries, the Alps and some parts of other mountainous areas, either disappearing from the higher mountains (Lichtenberger 1978, 1979) or undergoing a transformation into more modern more effective type Mma.

As far as market oriented agriculture (M) is concerned, which during the last decades almost entirely substituted the traditional agriculture in Western Europe, it is also undergoing transformation. On the one hand, as in France, with the growing size of farms large scale commercial agriculture (Ml) is expanding at the cost of small scale agriculture (Mm); on the other hand, within the same type of the second order less intensive types of small scale agriculture are substituted by more intensive types. Most of the newly described types are just those that replaced less intensive types by the more intensive types of the third order.

The same is true of the socialized farming (S). Rather extensive incipient socialized agriculture (Se) which earlier dominated in most of the countries of East-Central Europe and the USSR has survived only in some parts of Rumania and the USSR. On the other hand, intensive mixed agriculture (Smd) with livestock breeding prevalent, developed first in the German Democratic Republic, is now expanding in Czechoslovakia, Hungary and Poland substituting for less intensive mixed agriculture (Smm).

The same is true of the more intensive form of mixed agriculture with crop growing prevalent (Smu, Smi) which has almost entirely replaced former less intensive type (Smc).

The lack of earlier comparable material for the USSR makes it impossible to comment on those processes in that country. It would perhaps be worthwhile to draw attention to the most intensive types of mixed agriculture in the USSR, oriented mostly to crop growing (Smu) which cover large tracts of the Ukrainian Republic as well as some parts of southern Russia. Towards the East it is passing to types Smc and Sec which, though much less intensive, are more adapted to semi-arid conditions.

On the other hand large areas of the northern part of the USSR are still covered by the low intensive and low productive type of mixed agriculture with livestock breeding dominant (Sma).

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If such a typology is repeated after some years much more interesting conclusions could be made as to the tendencies in agricultural development and localization. Several such dynamic studies made for smaller areas brought about very interesting material (Stola 1975; Szczęsny 1979).

As it has been said at the beginning, the present map is a tentative one presented here both to inspire a discussion and to stimulate perhaps future attempts at mapping agricultural types elsewhere. All oral and written remarks and criticisms will be much appreciated and used in the further revised version of the map.

Before such a map is made, the following steps should be taken.

1. The material ought to be collected for the countries for which it is still lacking, i.s. Albania, Greece, Portugal and most of England.

2. For some countries as France and Norway the material ought to be brought to date.

3. For the countries the material has been completed for too large units as for Britain, Ireland, the Netherlands and Dennmark an additional data should be collected.

4. On the other hand the material for Macedonia ought to be computed for larger units than the communes. The material should also be completed for Croatia and Montenegro, for the socialized agriculture of Bosnia and Hercegovina and for smaller units of Slovenia.

5. All the collected material, expressed in codes should once more be compared with the codes of the model types by means of computer and either included in those types or used to describe new ones.

6. In order to simplify the picture, particularly in view of a possible reduction of the scale in printing, the identification of transitional forms between the types based on two successive products only should be considered and tested.

7. The legend of the map ought to be revised as regards its consistence and clarity.

It is hoped that the whole work will have been finished by 1982 and the map sent to the publishers.

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# TWO ISOPLETH MAPS OF WORLD POPULATION DENSITY CONSTRUCTED ON EQUAL-SIZE UNIT AREAS

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## INTRODUCTION

As the oldest measure of the distribution of population in geographical area, population density is, despite all of its simplicity, a very difficult issue in methodological terms. It is expressed in the formula:

$$D = \frac{P}{A} \text{inh./km}^2,$$

where $P$ — population, $A$ — area, $D$ — population density

Sources of these problems are manifold:

1. Population is distributed unevenly in the world.
2. Territorial and population statistics are inadequate, i.e. either no censuses have been conducted or the results of censuses have been published only in part.
3. Population density is computed for territorial units of very different sizes for which data from censuses are available.
4. There is a whole variety of systems of administrative divisions of countries — they comprise different numbers of subdivisions and units of different ranks vary immensely in area.
5. Cartographic methods of presentation of population density are applied arbitrarily and are often wrongly combined; as a rule no explanation is supplied on the basis of what territorial units the map has been made.

Here are interpretations and the most telling illustrations of the above statements:

Ad 1. The following examples are sufficient illustration of uneven distribution of population in the world:
The subarctic region of Canada vs. the north-eastern part of the United States;
The European subarctic region vs. Central-Western Europe;
The Sahara vs. the Nile Valley;
The Asian subarctic region vs. Japan, Eastern China, India and Java.

Ad 2. In order to realize the shortcomings of statistics, it is enough to mention two giants: a territorial giant-the USSR, and a population giant — China.

As concerns the USSR, which extends over 16.4% (nearly one-sixth) of the inhabited land, data on the territory and population of only 158

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territorial units, average area 141 787 km²,[1] have been published (according to census of 15 Jan. 1971). The units are constitutent republics, autonomous republics, autonomous oblasts, national okrugs, krays, and oblasts, there is an immense variety of size of their territories.

$$\frac{\text{minimum — the Adzhar autonomous republic}}{\text{maximum — the Yakut autonomous republic}} \quad \frac{300\ \text{km}^2}{3\,103\,200\ \text{km}^2} = \frac{1}{1034}$$

Besides, the Yakut autonomous republic and the constituent republics: Armenia, Azerbaijan, Estonia, Georgia, Lithuania, Latvia and Moldavia are not divided into oblasts (first rank units), but straight into rayons (second rank units), of which there are 3031 in the USSR, with average area 7349 km².

As concerns China, a population giant, in 1957 it released statistics merely for 29 territorial units with Peking and Shanghai (8900 km²), and exluding those cities, for 27 territorial units, average area 353 778 km².

Ad 3. It has been sanctioned by tradition that all statistical yearbooks publish population density data without considering the fact that population density depends on two variables: $\frac{P}{A}$ which means that the same population density may be a result of very different values of $P$ and A, e.g. $\frac{10}{1} = 10$ and $\frac{100\,000}{10\,000} = 10$.

Therefore figures for population density, assuming two input data, are utterly incomparable and merely characterize individual statistical units. They are only comparable when the units are of equal area or equal population, which in general terms is expressed as:

$$D = \frac{P}{A_{\text{const}}}, \quad \text{or} \quad D = \frac{P_{\text{const}}}{A}.$$

In practice it is easier to obtain equal-size fields (e.g. regular fields-hexagons), for which it is easier to compute population figures (see map, Fig. 2 with 100 000 km² units),[2] or to use geographical units obtained by way of adding smaller territorial units with known number of population to reach the assumed size (see map, Fig. 3, with 312 677 km² units). This is easier than the determination of equal-population fields. In practice, the situation

$$D = \frac{P}{A_{\text{const}}}$$

is preferred, the more so as figures in other issues (economic, physiographic) may be obtained for equal fields.

The enclosed Fig. 1 illustrates this reasoning. It gives very different population density figures for some territorial units of approximately the same size, or approximately the same population density for different sizes of the territory and population numbers.

Ad 4. Examples of area span within systems of administrative divisions are given in Table 1. Similar spans occur in all countries whose pop-

[1] Average area of voivodships in Poland = 6381 km²
average area of departments in France = 6129 km²
average area of counties in the USA = 2529 km²

[2] Figures 2–4 are enclosed separately under the back cover.

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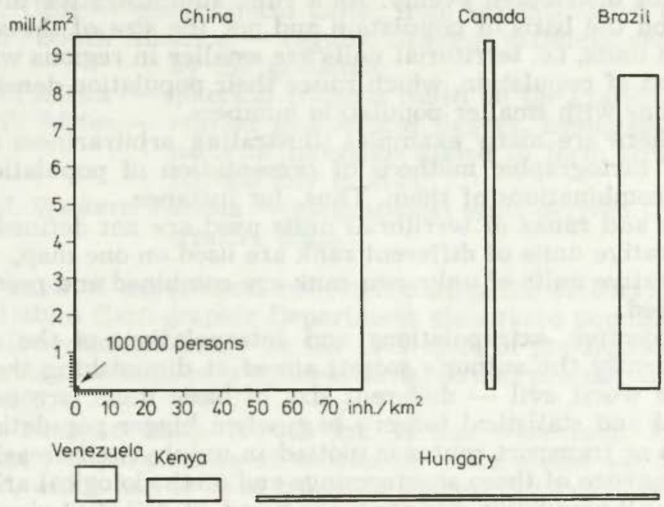


Fig. 1

TABLE 1. Variety of systems of administrative divisions (examples)

| Country | Territorial unit: kind | Territorial unit: name | Area km²: maximum | Area km²: minimum | Ratio max./min. |
|---|---|---|---|---|---|
| USA | states | Alaska | 1 540 196 | × | 489.9 |
| | | Rhode Island | × | 3 144 | |
| | | Texas | 692 408 | × | 220.2 |
| | | Rhode Island | × | 3 144 | |
| | counties | San Bernardino | 52 102.174 | × | 874.7 |
| | | New York | × | 59.6 | |
| | (independent city) | San Bernardino | 52.102.174 | × | 10 058.0 |
| | | Falls Church (Vi) | × | 5.2 | |
| USSR | constituent republics | Russian SFSR | 17 075 400 | × | 573.0 |
| | | Armenian SFSR | × | 29 800 | |
| | autonomous republics | Yakut ASSR | 3 103 200 | × | 1 034.4 |
| | | Adzharian ASSR | × | 3 000 | |
| | oblasts | Irkutsk | 745 900 | × | 191.3 |
| | | South Ossetian | × | 3 900 | |
| Algeria | departments | Oasis | 1 031 561 | × | 383.6 |
| | | Algeri | × | 3 393 | |
| China | provinces | Sinkiang | 1 646 800 | × | 283.9 |
| | | Shanghai | × | 5 800 | |

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ulation is not distributed evenly. As a rule, administrative divisions are performed on the basis of population and not the size of the area of administrative units, i.e. territorial units are smaller in regions with a large concentration of population, which raises their population density in relation to regions with smaller population numbers.

Ad 5. There are many examples illustrating arbitrariness in the application of cartographic methods of presentation of population density and wrong combinations of them. Thus, for instance.

— the kinds and ranks of territorial units used are not defined,
— administrative units of different rank are used on one map,
— administrative units of unknown rank are combined and pseudoisolines are introduced.

Any subjective extrapolations and interpolations of the eleborated maps (frequently the author's secret) aimed at diminishing the consequences of the worst evil — different size of basic units, are nothing but geographical and statistical forgery (e.g. when bigger population density along rivers or transport routes is plotted in uninhabited areas).

In consequence of those shortcomings and methodological arbitrariness (points 1–5), all population density maps based on different-size territorial units are both internally and mutually incomparable, albeit they are often presented as the only true and correct image.

* * *

It clearly follows from the above observations that nothing other than a population density map based on one variable-population number *P*, when the basic field is of a definite, uniform area *A*, can provide an objective and comparable image. This is expressed in the formula.

$$\frac{P}{A_{\text{const}}} = D \text{ inh./km}^2,$$

i.e. at constant area, population density is directly proportional to the number of population. Hence the fundamental statement that the object of comparison may be population density maps based on basic statistical units of the same size.

Unfortunately, the issue of selection of the size of the basic unit area is a methodological void. Only one thing is certain, namely the bigger the unit, the more generalized the image of the phenomenon.[3]

What remains is an empirical procedure. An empirically selected unit will be used within the given region regardless of the differentiation of population distribution. This will make possible comparisons of the phenomenon on different continents.

Apart from many works in Poland, the Cartographic Department of the Maria Curie-Skłodowska University in Lublin has considerable experience as regards the application to continental regions of uniform units of different size and derived in different ways.

10 000 km²: Europe — 'geographical units' derived from administrative units,

[3] One must not confuse the generalization of image which is a result of increasing the unit areas with the generalization which is a simplification of the ready image.

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50 000 km²: USA — 'geographical units', from administrative units,
100 000 km²: South America — regular fields of different shapes, bound by the graticule,
100 000 km²: Africa — spherical trapezia based on the graticule,
100 000 km²: Africa — regular geometrical figures, hexagons, peripheral parts of hexagons added to form irregular units 100 000 km² in area,
312 677 km²: Western Eurasia — geographical units derived from administrative units.

On the basis of experiences collected during the elaboration of those maps, the Lublin Cartographic Department elaborated population density maps for all continents based on the 1970 state of population. The maps were elaborated in Lambert's equal-area azimuthal projection at the scale of 1:20 000 000.[4]

Regular hexagon units, 100 000 km² in size were used. Parts of the hexagons on the peripheries of continents were added up to area size 100 000 km², which had to be of irregular shapes. Centres of hexagons and centres of area of peripheral, irregular fields were adopted as control points for figures on population density in fields; they were linked by triangularly arranged interpolation axes.

In order to compute population number in 100 000 km² unit areas a dot map of population distribution with dot weight 100 000 inhabitants was made for each continent (the most difficult task). The map was completed with a distribution of cities over 100 000 population. The sum of the statistical value of dots and the number of population in the cities was the total number of population for each field, from which population density within fields was easily computed: 100 000 population → inh./km².

An interpolation of isopleths (along interpolation axes) and plotting them, as is the custom at the Lublin centre of cartography, in the form of straight lines crowned the process of elaboration of maps of population density of continents, for the first time constructed on equal-size fields.

## MAP OF WORLD POPULATION DENSITY ON 100 000 km² UNIT AREAS

The map was elaborated in transverse Lambert's equal-area azimuthal projection for the world, with projection centre: $\varphi = 0°$ and $\lambda = 20°$E in the form of F. Uhorczak's map 'World in a Circle'. It provides for the best mutual arrangement of continents in relation to the centre of continental masses (in Africa) or many maps of the world. Owing to the symmetry of the graticule in relation to the equator, it provides a very good picture of regions situated concentrically to the poles (very deformed on regular Mollwaide's[5] or Eckert's projections), which is particularly important in the case of the Arctic (polar concentricity of continents).

[4] Authors of maps: Africa — W. Domaszewicz, Eurasia — E. Kahanek, North America — J. Drozd, South America — E. Dudek, Austrialia — L. Grzechnik.

[5] In Mollweide's transverse projection, with centre $\varphi = 50°$N and $\lambda = 20°$E, widely used by F. Uhorczak for world maps in *Geografia Powszechna* (World Geography), PWN, Warszawa 1962–1967, the polar concentricity of the Arctic region even more visible, but Antarctica is divided in two parts.

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The above mentioned population density maps of continents were used as source material in the elaboration of the map of the world. The main methodological problem is how to transfer the image of population density of continents onto the map 'World in a Circle'. It was solved by way of transferring centres of geometrical unit areas (control points for population density) and a new interpolation of isopleths, which were plotted in the form of straight lines, like on the maps of continents.

Due to the very big span of population density within fields, which ranged from 0 to 570.6 inh./km², and with an eye to obtaining a clear picture, a uniform scale of isopleths was used according to a geometrical progression with intervals growing 2-fold: 0, 5, 10, 20, 40, 80, 160, 320, and 640 inh./km². This seven-grade system of isopleths was complemented with an extra isoline whose value was 1 inh./km² did not disturb the geometrical progression and excellently brought to light regions with the lowest population density (0–1), which occur on all continents in large, geographically characteristic patches. The growing intervals of the geometrical scale sufficiently emphasize regions of highest population density on continents.

Naturally, the arrangement of isoplethes does not agree with the transformation of projection from maps of continents to the map of the world. In this way curvilinear isolines with different deformations of distance between them were avoided. A new picture of isolines was obtained by way of interpolation of equal-value centres of geometrical fields correctly transferred from the maps of the continents. The isolines of Africa were the only ones not to undergo deformation, as the centre of projection of the map 'World in a Circle' is identical to that on the map of this continent. Deformations increasing together with distance from the centre of projection do not change the fundamental picture of isolines. Owing to their arrangement, the image of population density may be interpreted in a way identical to that in the maps of continents, it is enhan'ced by their geographical proximity, very well presented on the map 'World in a Circle'. This is particularly true of the subecumena of the northern hemissphere, where population densities ranging from 0 to 1 inh./km² are very conspicuous owing to the polar concentricity of Eurasia and North America.

Considering the picture of regions bound by the 1 inh./km² isolines alone, one obtains a lot of geographical information owing to full comparability of image and the generalizing action of relatively big fields, the size of which corresponds to whole countries in Europe (e.g. the GDR with area 108 300 km² and population density 157.5 inh./km²).

The big features of the comparable image of population density are just as discernible in the other part of the scale, that of the highest population densities. The map provides an excellent presentation of well-known densely populated regions of Central-Western Europe, Bengal, Eastern China or the world culmination on Java (570.5 inh./km²), or the culminations of Africa and the Americas, twice or three times lower, and the slight culmination of Australia. With the exception of the West European, they all share one feature — they are situated in eastern coasts of continents.

Apart from this general glance at the big features of population density of continents, two more observations confirm the applied size of fields and the isopleth method. The first is related to the clearly visible strip of

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higher population density in the USSR — from Leningrad, through Moscow and Chelyabinsk, along the Trans-Siberian Railway to Krasnoyarsk. When 100 000 km² units are used, the uneven distribution of population in this region is emphasized. The other observation is related to Eastern China, where the location of 5 inh./km² isopleth is consipicuous. This isopleth nearly exactly separates the administrative provinces of Eastern China, which, with 57.7% of the country's territory and 97.5% of the population (1957), have average population density 114.2 inh./km², from three western provinces; Inner Mongolia, Tibet and Sinkiang, which account for 42.3% of China's territory, 2.5% of the population, and have population density 4 inh./km². Maximum population densities within unit areas for continents and selected regions are given in Table 2.

TABLE 2. Maximum population density of fields in selected regions

| Continent | Region | Maximum population density of field inh./km² | Population in field 100 000 km² |
|---|---|---|---|
| Asia | Western Java | 570.6 | 57 060 000 |
| | Bengal | 541.1 | 54 110 000 |
| | Shanghai area | 506.6 | 50 660 000 |
| | Japan–Hondo | 348.7 | 34 870 000 |
| Europe | North-Western France | 330.8 | 33 080 000 |
| North America | East Coast Megalopolis | 275.7 | 27 570 000 |
| South America | Rio de Janeiro area | 144.3 | 14 430 000 |
| Africa | Nile Delta area | 204.5 | 20 450 000 |
| Eurasia | USSR–European part | 227.0 | 22 700 000 |
| | USSR–Asian part | 52.9 | 5 290 000 |
| Australia | Sydney area | 40.5 | 4 050 000 |

## MAP OF WORLD POPULATION DENSITY ON 312 677 km² UNIT AREAS (EQUAL TO POLAND'S AREA)

The plotting of world population density on fields 312 677 km² in area is the first attempt at applying so big equal-area fields in a map of population density of the world (continents). As concerns the method, the project is a continuation of the earlier described work on population density of continents plotted on 100 000 km² hexagon fields.

The intention underlying the selection of this size of basic unit area was to elaborate a map on the basis of a field which would be several times bigger than those on which maps had already been plotted. As the 300 000 km² field (three times as big) differs very little from the area of Poland, 312 677 km² field was adopted (which meant a 4.2% increase on 300 000). The advantage is that for the first time one is able to compare population density of world regions with a concrete territory, Poland in this case. Thus, the map is 'polonocentric'.

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The elaboration of this map differs only in the method of obtaining equal-size unit areas. As it was said earlier, when overlaying a system of regular fields (e.g. hexagons), it is necessary to add up parts of hexagons on the perimeter of continents to obtain the adopted size. When fields are bigger (in this case, three times as big), it is much more difficult to add up the fragments and extremely elongated fields are obtained.

Therefore a simpler, geographical-statistical method (introduced by F. Uhorczak) of obtaining those fields was applied in the elaboration of the map based on 312 677 km² unit areas. The method consists in adding up the area of different rank administrative units (starting from small countries), for which the statistical size of the area and the number of population are available.

The minor operations of dividing bigger administrative units in order to obtain the desired size of fields call for extrapolation of the number of population in those regions. The error of estimation of this extrapolation, which equals 31 268 inhabitants, amounts to 0.1 inh./km² and is surely lower than in the elaboration of a dot map for sparsely populated regions, which is necessary when regular fields are applied.

As a result, obtained were unit areas of the desired size or very near the desired size, when it was more convenient not to divide small units in order to obtain precisely the assumed size of fields. In practice, this happened rarely, and in individual extreme cases the deviation of unit areas size was no more than ± 3%, which usually resulted in negligible differences in population density within fields. One aim was to preserve a possibly compact, not a dismembered shape of the field.

Since it was assumed that the ultimate map would be elaborated using the isopleth method (like the earlier described map), control points had to be located for the purpose of interpolation of isolines. This was done by determining centres of area of irregular fields with the use of the rudimentary method of 'weighing' fields with a perpendicular. The control points for figures on population density within fields obtained in this way were linked with interpolation axes arranged in triangles, according to the principle of closest proximity of control points.

Continents were divided into 312 677 km² fields on maps of administrative divisions at larger scales, and centres of area of fields — control points were transferred with the use of geographical graticule co-ordinates on the ultimate base map 'World in a Circle' (see above) at the scale of 1:20 000 000 and an interpolation of isolines was conducted at this scale. The ultimate map of world population density was obtained by photoreduction to scale 1:50 000 000.

All the statements concerning the earlier described map are valid for the whole process of elaborating this map. Let us just repeat the scale of isopleth values: 1, 5, 10, 20, 40, 80, 160, 320 inh./km² as the basis for comparison of the two maps.

The result of the work is the first-ever comparable map made on the basis of what are for European conditions quite big unit areas. Table 3 gives the division of continents into fields selected for the two maps.

Despite the small number of fields (e.g. 16 for Western Europe and 97 for Africa), i.e. also the small number of population density figures, an extremely clear nad geographically convincing picture of population density of the world and continents was obtained. It had the fundamental features of the isopleth map — the image was compact and generalized.

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TABLE 3. Division of continents into 100 000 km² and 312 677 km² fields

| Continent | Area thousands km² | Approximate number of fields | | Ratio of numbers of fields |
|---|---|---|---|---|
| | | 312 677 km² | 100 000 km² | |
| Europe (excl. USSR) | 4 958 | 16 | 50 | 3.125 |
| USSR | 22 275 | 71 | 223 | 3.141 |
| Asia (excl. USSR) | 27 560 | 88 | 275 | 3.125 |
| Africa | 30 319 | 97 | 303 | 3.124 |
| North America | 24 247 | 78 | 243 | 3.115 |
| South America | 17 833 | 57 | 178 | 3.123 |
| Australia (excl. West Irian) | 8 511 | 27 | 85 | 3.148 |
| Land (excl. Antarctica) | 135 703 | 434 | 1 357 | 3.127 |

It is worth noting that this is the first chance to analyse comparatively (in relation to 100 000 km² unit area map) the influence of more than a tree-fold increase of the basic unit area on the general image of population density. To put it briefly: in line with the law of image generalization, when the basic field is increased, the main features of the phenomenon are preserved, maximum values are diminished, small areas disappear, the range of areas with the lowest population density, from 0 to 1 inh./km² is diminished, and the areas of average values grow. All in all, the image is very similar, only it is more compact and features fewer details, in accordance with the generalizing action of bigger fields.

This is also the first chance to compare the population density of various regions with Poland (as the basic field has the size of Poland's territory), which was also plotted graphically by introducing the isoline of 104 inh./km², the average population density of Poland at that time (1970). One can indicate regions more densely or sparsely populated than Poland. The latter clearly prevail.

For methodological reasons, it is also worth noting that the introduction to the map of the average (or other selected) value of a phenomenon with the use of the same graphical method (isopleth) is only possible when applying the isopleth method.

## GRAPHICAL ANALYSIS OF POPULATION DENSITY OF CONTINENTS AND PARTS OF CONTINENTS

Table 4 shows the per cent share of particular zones (degrees) of population density of selected regions (continents and parts of them).

Figures contained in this table make possible the plotting of a volumetric for each region, modelled on the hypsograhic curve, a 'densigraphic curve' in this case, which provides for computing average population density of the investigated region as a result of measurement of the area of zones on the isoline map (one of its main advantages). The volumetric mean is the only mean available for regions for which no statistical mean is available. When compared with the statistical mean, it provides for a measure of control of correctness of the isopleth map (see below).

Table 5 shows the results of the first attempt at a comparison of the average population density of continents, obtained from the densigraphic

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TABLE 4. Per cent share of particular zones of population density in selected regions (continents and parts of them)

| Row | Zone | Region | Europe | | USSR European part | Asia without USRR | Eur-asia | Asia Total | Africa | America | | USSR | | Australia without islands | World without Papua-New Guinea and small islands |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Western | Total | | | | | | South-ern | North-ern | Total | Asian part | | |
| | No. | Density inh./km² | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| 1 | 1 | 0–1 | 1.4 | 3.4 | 5.3 | 10.1 | 21.9 | 26.2 | 22.4 | 29.6 | 40.3 | 41.3 | 52.5 | 79.9 | 29.6 |
| 2 | 2 | 1–5 | 9.2 | 14.1 | 18.8 | 17.2 | 17.5 | 18.3 | 22.5 | 26.0 | 19.0 | 19.8 | 20.1 | 9.6 | 19.6 |
| 3 | $\Sigma 1+2$ | 0–5 | 10.6 | 17.5 | 24.1 | **27.3** | **39.4** | **44.5** | **44.9** | **55.6** | **59.3** | **61.1** | **72.6** | **89.5** | **49 2** |
| 4 | 3 | 5–10 | 4.0 | 7.7 | 12.2 | 9.0 | 9.6 | 10.0 | 23.2 | 13.9 | 9.7 | 11.6 | 11.8 | 6.2 | 13.1 |
| 5 | 4 | 10–20 | 4.5 | 7.1 | 9.6 | 9.9 | 8.9 | 9.4 | 19.6 | 13.7 | 9.2 | 8.9 | 8.5 | 1.8 | 11.6 |
| 6 | 5 | 20–40 | 4.9 | 15.6 | **25.6** | 11.8 | 10.6 | 9.4 | 8.2 | 12.0 | 13.4 | 10.2 | 5.5 | 2.4 | 10.3 |
| 7 | 6 | 40–80 | 22.1 | 21.8 | 21.5 | 13.4 | 11.3 | 9.0 | 3.2 | 3.8 | 4.8 | 6.3 | *1.6* | *0.1* | 6.7 |
| 8 | 7 | 80–160 | **39.8** | **23.0** | 7.2 | 12.4 | 10.6 | 7.7 | 0.7 | *1.0* | 3.0 | 1.7 | — | — | 5.1 |
| 9 | 8 | 160–320 | 14.0 | 7.2 | *0.8* | 12.1 | 7.5 | 7.5 | *0.2* | — | *0.6* | *0.2* | — | — | 3.2 |
| 10 | 9 | 320–640 | *0.1* | *0.1* | — | *4.1* | *2.1* | *2.5* | — | — | — | — | — | — | *0.8* |
| 11 | 1–9 | 0–640 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| 12 | $\Sigma 1+2$ | 0–5 | 10.6 | 17.5 | 24.1 | 27.3 | 39.4 | 44.5 | 44.9 | 55.6 | 59.3 | 61.1 | 72.6 | 89.5 | 49.2 |
| 13 | $\Sigma 3$ to 9 | 5–640 | 89.4 | 82.5 | 75.9 | 72.4 | 60.6 | 55.5 | 55.1 | 44.4 | 40.7 | 38.9 | 27.4 | 10.5 | 50.8 |
| 14 | Maximum population density inh./km² | | 330.8 | 330.8 | 227.0 | 570.6 | 570.6 | 570.6 | 204.5 | 144.3 | 275.7 | 227.0 | 54.1 | 40.5 | 570.6 |

The regions have been arranged in columns 1 to 12 by a growing share of zone 1+2: 0 to 5 inh./km² (row 3). Rows 1 and 2 (brevier type) feature per cent shares of the area of the first zone: 0–1 inh./km² and the second zone: 1–5 inh./km², in order to especially emphasize the first zone (0–1 inh./km²), in regard to which there are clear differences between the regions—Western Europe: 1.4% and Australia: 79.9% of the area. Row 12 (repeated 3) again displays the increasing series of regions by per cent share of area of the first and the second zones (0–5 inh./km²); row 13 (which together with row 3 totals 100%) gives prominence to the decreasing series of regions by per cent share of area of zones 3–9: 5–640 inh./km². Figures in bold type and in italics show the maximum and minimum shares of individual regions. Mention is due to column 13, which illustrates the shares of population density zones of the inhabited continents. Looking at row 3 of this column, one will observe that 49.2% of the inhabited continents belong to zone 0–5 inh./km², naturally when basing on 100 000 km² unit areas. The table closes with row 14, which illustrates maximum population density of regions basing on 100 000 km² unit areas.

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TABLE 5. Mean population density of continents — statistical and densigraphic

| Continent | Area thousands km² | Population 1970 thousands | Mean population density | | |
|---|---|---|---|---|---|
| | | | statistical inh./km² | densigraphic inh./km² | densigraphic per cent of statistical |
| Europe | 10 502 | 648 000 | 61.7 | 62.5 | 102.9 |
| Eurasia | 54 841 | 2 761 000 | 50.3 | 50.0 | 99.4 |
| Asia | 44 339 | 2 113 000 | 47.7 | 47.5 | 99.6 |
| North America | 24 247 | 321 000 | 13.3 | 13.2 | 99.3 |
| Africa | 30 319 | 343 000 | 11.3 | 10.8 | 95.6 |
| USRR | 22 275 | 242 768 | 10.9 | 12.3 | 112.8 |
| South America | 17 833 | 190 000 | 10.7 | 10.5 | 98.1 |
| Australia | 8 511 | 19 400 | 2.3 | 2.0 | 87.0 |

curve on the isopleth map constructed on the basis of equal-area 100 000 km² unit areas, with the statistical average population density.

We had no experience in comparising the mean derived from the densigraphic curve with the statistical mean and the interpretation of differences between them, especially for such vast areas as continents and with such a large span of population density and area of extreme zones. Therefore the obtained results of measurements of the densigraphic mean can only be treated as tentative, albeit the figures obtained seem surprisingly correct (with the exception of the USSR — big difference 112., and Australia — 87.0). If the results of the comparison are considered positive, it seems right to assume that the applied method of testing the correctness of the elaboration of the isopleth map—a comparison of the statistical and the densigraphic mean confirm the statistical measurability of a well made isopleth map.

### DENSIGRAPHOIDS OF CONTINENTS

The figures on the area between isopleth (zones of population density) quoted in Table 4 also make possible the construction of a model of population density of a continent — a densigraphoid, analogous in method to F. Uhorczak's 'hypsographoid' of 1930.

A perfect isopleth 'map' of population density of continents is plotted in the form of a circle, equal in area to the area of the continent. Concentric rings of lowest value 0–1 inh./km² aid subsequent values 1–5–10.... etc., correspond to the area of individual zones of population density. The centre of the circle map corresponds to the highest population density in the given region.

The vertical profile (section) of the perfect circle 'map' is the cross-section of a solid of revolution — a densigraphoid, which is a graphic synthesis of the image of population density in the given region. The shapes of densigraphoids of continents are so varied that it is quite sufficient to interpret them visually (Fig. 4). The interpretation may be additionally enriched by a superimposition of two densigraphoids. No other graphical method provides such a rich visual illustration.

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TABLE 6. Maximum population densities of selected regions according to the two maps

| Continent | Region | Maximum values on maps with fields km² | | Differences in relation to 100 000 km² fields | |
|---|---|---|---|---|---|
| | | 100 000 | 312 677 | inh./km² | per cent |
| | Indonesia | 570.6 | 288.9 | 281.4 | 50.6 |
| | Bengal | 541.1 | 354.7 | −186.4 | 65.6 |
| | Eastern China | 506.6 | 402.0 | −104.6 | 79.4 |
| | Japan | 348.7 | 289.9 | −58.8 | 83.1 |
| Western Europe | Central-Western Europe | 330.8 | 249.4 | −81.4 | 73.4 |
| North America | East Coast Megalopolis | 275.7 | 114.9 | −160.8 | 41.7 |
| Eurasia | USSR–European part | 227.0[a] | 80.7[b] | −146.3 | 35.6 |
| | USSR–Asian part | 52.9 | 43.9 | −5.6 | 83.0 |
| Africa | North-Eastern Egipt | 204.5 | 107.1 | −97.4 | 52.4 |
| South America | Rio de Janeiro area | 144.3 | 62.7 | −81.6 | 43.5 |
| Australia | South-East | 40.5 | 12.8[c] | −27.7 | 31.6 |

[a] Moscow area, [b] Donbas, [c] Area south of Sydney

As for the time being it is not possible for us to conduct a comparison of densigraphic means and densigraphoids on 312 677 km² unit areas, a comparison of maximum population densities in large regions is given in Table 6. With the exception of the clear change in maximum regions (USSR, Australia), on the basis of per cent change (last column) one can observe that the preserved maximum is relatively high (higher per cent value) in regions where bigger population concentrations occur in vaster areas and a lower per cent value of the preserved maximum occurs in clustered concentrations of population.

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# ORIGIN, DEVELOPMENT AND CONTEMPORARY RENAISSANCE OF RELIEF SHADING ON MAPS

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The present paper is a general survey of factors responsible for the fact that is was not until after World War II that the shading of relief on maps became videspread. The tendency to take a critical view of the features or properties of shading is now a matter of the past and an increasing number of studies are published which present the opportunities for the use of this method on different kinds of maps. Three essential factors have influenced the career of shading in cartography:

— the development of cartographic technologies,
— the experiences of the period of hachure cartography,
— the origins and dynamic development of thematic cartography after World War II.

The title of the paper is not intended to indicate that shading of terrain relief on maps has been through a time of decline, it is to emphasize that this method has recently become widespread and accepted by cartographers. At present, the question whether to employ shading is resolved on the basis of the content and purpose of the map and the skill and technology available to the publisher. A proof of this are a number of national atlases (*The Atlas of Britain*, 1963) which simultaneously employ contours, hypsometric or shading relief presentation.

The method of shading relief on maps has a complicated and fascinating origin and history. On the one hand, it is difficult to ascertain when shading appeared on maps or who was its author, as the origin of this method was a natural consequence of the progress of maps. On the other hand it was not until the invention of lithography that multitone sheets could be printed, i.e. a technology for this method of relief presentation on the map was elaborated. Opportunities for the printing of shading grew together with the progress of the planographic printing technology. The invention of screens, and the half-tone screen in particular (Meisenbach 1884) finally seled the period of development of the technology base for the reproduction and printing of shading. Owing to this invention, it was possible to transfer the elaboration of the half-tone oriqinal of relief from the printing form to the drawing paper. The original could subsequently be photographed with the use of a screen. The application of the half-tone screen was the final part of the formation of the technological base of modern shading. All the subsequent changes have been improvements on this base.

Prior to the development of technological conditions for the reproduction and printing of shading, a number of maps were elaborated which

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employed the light-and-shade effect to represent relief. The 'hillock' manner excepted, on many maps the surface-continous representation of relief reached a level for many vears unattainable to 'printed' shading. Even if Leonardo da Vinci's map of Tuscany of 1502 is to be included among paintings, Gyger's map of the Zurich canton of 1667 be considered a purely cartographic work. More than that, it is a physiographic map made 300 years before the 'invention' of our contemporary cartography.

The technological means making possible correct reproduction and printing of multi-tone maps were not finally developed until late 19th century. Thus, a whole epoch of hachured maps came between the maps which could be considered the prototypes or the first shaded representations of relief and the development of means for printing them. Apart from all the theoretical foundations, hachured maps were based on the use of the light-and-shade effect to produce an impression of the third dimension of the plane.

Owing to the introduction of the lithographic technology to cartography, hachures could be replaced by continuous surface. All the rules for producing the impression of the third dimension remained unchanged. Thus, the passage from hachures to shading of relief can mainly be ascribed to practical reasons, i.e. the fact that the time of elaboration of the map was clearly reduced owing to the surmounting of problems related to the elaboration of relief. One must note the major change introduced by the shading worked in the understanding of relations between the map and the terrain. At least in the case of vertical illumination, the hachuring method tried to use appropriate formulae and rules to govern the relationship between slope and the brightness of the surface on the map. In practice, it was not really possible to read slopes from the map, but there were principles or rules that one could always refer to.

As vertical illumination produces an image of poor visual appeal, a major departure from the hachuring method was made when in mid--19th century Dufour applied oblique illumination. This meant that priority was given to the visual qualities produced by this kind of illumination rather than to appearances of exact correspondence between hill slopes and the brightness of their surface on the map. Shading from the very start recognized the priority of visual appeal. At the same time, it adopted the 'painter's technique' of producing the light-and-shade effect. This gave rise to allegations that shading is of poor value as it represents relief in a very subjective manner. Some cartographers placed shading on the margin of cartographic methods of relief representation on the map and considered it useful on posters and advertizing or propaganda publications of the kind. Frankly, one must admit that the beginnings of shading were a step backwards in comparison with the graphic perfection that copperplate engraving ensured to the hachuring method. As it appeared easy to perform shading and, indeed, initially cartographers displayed considerable arbitrariness and an excessively artistic approach to relief, the shortcomings of the execution were taken for the features of the method itself. Those beginnings of shading gave rise to many misconceptions about the whole method.

Beyond doubt those centres which could boast of the greatest achievements in hachure cartography were the best equipped to employ shading. Despite that, many of those centres waited a long time, often till World War II. The reasons which shaped the individual attitudes to shading

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were manifold. One of them was the presence or lack of tradition in the field of hachure representation of relief.

On the one hand, the countries with traditions of hachure cartography had many complete series of topographical maps made with the use of this method. On the other map users, schools and the army had grown used to this manner of relief representation. It was difficult for those countries to opt unequivocally for shading and, in addition, the first fully modern contour maps appeared in the 19th century. Therefore in many countries it was the contour map or the hypsometric map which succeeded the hachure map.

Owing to the converging principles of construction of the image of relief with the use of hachures and shading, only different methods of elaborating the original relief had to be employed. There was no such convergence as regards the technological requirements. Although shading reduced the difficulties and the amount of labour devoted to the making of the original, it posed decidedly greater requirements in the field of reproduction and printing. As a result, the countries best prepared to apply shading were those with long traditions and a high-standard technological base of cartography. However, as it was mentioned earlier, their options were restrained by the tradition of the hachure map. Thus, initially shading did not come to be fully accepted in any cartographic centre, for either there were no properly prepared cartographers and technological opportunities or the centres already possessed hachure maps.

In the second half of the 18th century the French cartography, and soon afterwards the Swiss and the German inaugurated the history of hachured relief presentation on the map. In France hachures were employed by Cassini on the map *Carte Géometrique de la France* at the scale of 1:86 400 elaborated in the years 1750–1815. In Switzerland, the *Atlas der Schweiz* at the scale of 1:108 000, commonly called the Meyers Atlas was elaborated in the years 1786–1802. Finally, in 1799 in Germany J.H. Lehmann made a major step which provided the theoretical foundations for the method and thus ended the period of the application of the so-called wild-cat hachures, i.e. hachures which were not related to the terraine by means of any precise rule. The hachuring method enriched cartography with two important elements: the representation of relief features in accordance with their horizontal outline, and the marking of the shapes of those features with the use of the light-and-shade effect, which might be produced by a vertical and orthogonal illumination of the earth's surface. Lehmann provided the theoretical foundations for precise correspondence between the slopes and the degree of brihtness of their surface on the map.

Although correct, this method did not ensure cartometric properties to hachuring. However, it did make other cartographers realize what immense prospects there lay in the use of hachuring to produce the impression of the third dimension on the map. In Switzerland, Dufour took advantage of those opportunities when in the years 1842–1864 he elaborated the excellent map *Topographische Karte der Schweiz* at the scale of 1:100 000. This work brought to light the vast opportunities for a suggestive presentation of relief features with the use of oblique illumination. Moreover, the map gave rise to the controversy, which continues till the present day, on the direction and angle of incidence of light rays on a place, and on the reliability and research value of such a way of presentation of relief on the map. All the critical opinions were later applied to sha-

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ding, which, combined with its graphic form, was responsible for the fact that shading was long considered a second-rate method.

Despite the disapproval of the introduction of oblique illumination, the masterly execution of the map made it a leading achievement of 19th century hachure cartography. Moreover, the visual appeal of the presentation of relief on this map made many cartographres employ oblique illumination. Dufour's map clearly prolonged the period of using hachures, as it resfored the visual suggestiveness to maps withing what was then the accepted graphic manner. It was as late World War II that marked the end of the hachuring epoch in cartography. That was largely due to the great damage the war brought in the archival records of topographic services and publishing houses. After the war, cartographic resources came to be reconstructed under changed conditions, hence topographic cartography opted chiefly for the contour map or the contour-and-hachure map.

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The progress of shading in Polish cartography took a different courses. As we did not have our own tradition in the field of hachure cartography and Polish cartography was absent from world cartography in the 19th century, when Poland regained independence in 1918 Polish map makers did not face a dilemma of choice between tradition and the already firmly estabilished contour method. At that time, shading could not possibly have been considered an option because the budding Polish cartography had virtually no personnel skilled in this method. The situation was similar in printing. As a result, during the two inter-war decades shading was altogether absent from school cartography and, as regards topographic maps, it was not until the 1930s that the Military Geographical Institute started to publish maps with slightly shaded contour picture of relief.

However, what has been written above does not explain the evident lack of interest or even resentment to shading cherished in the Polish inter-war cartography. Both attitudes could be attributed to the circumstances of the origin and development of our cartography at that time. One may claim that the attitude of Poland's leading cartographer Professor Eugeniusz Romer, who did not like shading, largely determined the views of all of Polish civil cartography, notably school cartography. Romer's stance dates to the year 1908, when the first edition of his Geographical Atlas appeared. The atlas undoubtedly opened up the period of contemporary Polish school cartography and at the same time initiated Romer-style cartography. In this first of his works, Professor Romer opted entirely for the hypsometric presentation of relief on a school map. Later, when the Książnica-Atlas publishing house grew in Lwów and came to be the leading publisher in Poland civil cartography, Romer extended his viewpoint to cover all of the cartographic output of this house. Romer's individuality, prestige and his international standing were enough to consolidate the position of the hypsometric and contour presentation of relief on Polish maps. The military topographical service founded in 1918 and represented by the Military Geographical Institute was independent of the views and decisions of Professor Romer. Owing to that, the Military Cartographical Institute could assume a more liberal attitude towards shading. However, it did not bocome widespread there either, not even on sheets of maps covering Polish highlands and mountains.

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The occasional use of shading on topographic and reference maps was due more to the commitment of individual cartographers employed there than to some general plan in this field. The first slightly shaded maps were brought out by the Institute in the 1930s. The chief advocate of those maps was Dr. Pietkiewicz, who was drawing on the experiences he collected during his studies in Switzerland. Pietkiewicz also wrote the treatise *Metody przedstawiania rzezby terenu na mapach* (Methods of presentation of relief on maps) (1930), the only work on the subject in Polish cartopraphis literature of the inter-war period.

As concerns topographic cartography, one must look for reasons in the circumstances of its origin after Poland regained independence in 1918. As from the fall of the 1830 November uprising the country did not have its own topographic service, no tradition of the Polish topographic map developed. In those circumstances, under Romer's influence, in 1908 all of the Polish civil cartography resolved to use the hypsometric method, and in 1918 a similar choice was made by the military cartography, which considered the contour map to be the essential method.

The lack of 19th century tradition of a Polish hachure or later a shaded map was not the only factor which shaped the model of Polish cartography in the field of representaition of relief on the map. Apart from the influence of Professor Romer's views, another equally important factor was the lack of draughtsmen cartographers who would make this kind of maps. Also important was the fact that, although the developing 'independent' Polish cartography had quite a large set of topographic maps, they had been elaborated by the partitioning states, hence they could not be treated as a model for continuation. Besides, those maps represented three cartographic schools — the Austrian, the Prussian and the Russian. As Polish cartography at that time was not burdened with the 19th century model of the map, and hachure cartography was clearly giving way to contour and hypsometric maps, Polish inter-war cartographers made nearly exclusively contour and hypsometric maps. This choice, undoubtedly the right one, soon allowed Polish cartography to catch up with the European lead.

Thus, it was due to historical reasons that Polish cartography made virtually no contribution to the development of shading. Actually, it cherished a critical attitude to this method. This long-time disapproval was reflected in the controversies provoked even after World War II by any attempt at applying shading on school maps. Both cartographers and teachers unanimously claimed that the introduction of shading on a hypsometric map does more harm to the correct representation of vertical relief than it adds to the visual appeal of the map.

* * *

The damage, especially severe at the end of World War II, speeded up the abandonment of hachures in topographic cartography for the sake of contour plotting. The contour representation of relief created natural conditions, as it were, for a gradual introduction of shading to topographic maps, thus improving their legibility. However, it should be noted that, tourist maps excepted, topographic maps made no major contribution to the propagation of shading in cartography in general. Relief is the number one element of the content of those maps, and shading is applied above

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all for practical reasons, as it serves to enhance the legibility of the contour representation of relief. In this situation, the presentation of relief on the map remains the fundamental task of contours, whereas shading plays the supplementary role of enhancing its legibility That often had negative consequences for shading, as it was often performed mechanically, without taking due care of full correspondence with the contuor representation of relief. This is best illustrated in the use of the Polish terms denoting a 'slightly shaded map', which sets it apart from a shaded map. Thus, it will be seen that the changes in the method of representing relief on topographic maps should not be considered the most important reason for the recent spread of shading.

The most important reason for the dissemination of shading was doubtless the increasing significance and the appearance of ever new thematic maps. Covering a huge range of issues, those maps forced cartographers to search for such solutions which would make relief the most conspicuous on maps, but not at the expense of their essential content. The contour method does not satisfy this condition, as this representation of relief has too little visual appeal. Moreover, isolines such as contours make it next to impossible to use this method for the remaining content of the map, similarly as the areal method. With all its advantages, the contour image cannot provide for direct correspondence between the issue presented and the terrain condition of the given area. An illustration may be the dependence of temperatures, precipitations, the distribution of crops or arable land on relief.

Another reason for the general interest of cartographers in shading is its areal-continuous approach to the topographic area. In contour representation, the selection of contours and their schematization may only be increased to a certain level. When a certain level of generalization is exceeded, it is no longer a representation of relief, but of relations of altitude. Moreover, incoherence creeps into such an image and the map user is practically deprived of the chance to read from the map the relationships of dependence which occur between the relations of altitude and the phenomenon which is the proper content of the map.

At thematic maps progressed, the range of map users grew. The map has become one of the most important means in the presentation of findings of natural and social sciences. The map has also become generally recognized as the most effective method of presentation of all spatially distributed phenomena. Many of them cannot be understood until they are presented in a cause-and-effect approach on the map, and shading is one of the methods which provide such opportunities. A generalization of shading does not reduce its legibility, therefore it is useful both for large and small scale maps.

When analysing the reasons for the interest contemporary cartographers take in shading, one must not ignre the great individuality of E. Imhof. I do not hesitate to claim that in a sense he is the real author of contemporary shading and the man to be credited for the fact that shading was granted rights equal to those of other methods of representation of relief on maps. His long-time vigorous cartographic activity and the publication of the fundamental work *Kartographische Geländedarstellung* (1965) may be compared to Eckert's achievements in the field of elaborating a modern approach to cartography in an equally fundamental work *Die Kartenwissenschaft* (1921, 1925). Owing to his unusual talent and

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consistent work, Imhof inoculated shading against the traditional charges alleging it lacked cartometric properties or sufficiently precise theoretical foundations. Imhof's practical activity confirmed the validity of the opinion that shading is the most natural and at the same time a fully cartographic method of representation of relief on the map. He also invalidated the thesis that artistic qualities of shading wipe out or diminish the objectivity and consequently the research value of this method. Imhof is one of those cartographers who tested their views in practical work in nearly all the branches of cartography. Imhof's decades-long practical work supplied illustrations for the application of shading on large scale maps, such as the *Schaffhausen Canton* at the scale of 1:75 000 (1954), school atlas map in the *Schweizerischer Atlas für Sekundärschulen* (7th edition 1957) and the national atlas of Switzerland *Atlas der Schweiz* published in the years 1965–1978. Many of those maps are examples of Imhof's style and mastery.

Also Wenschow made great contributions to the propagation of shading. Although he is mainly associated with photorelief, one cannot ignore Wenschow's contribution to the propagation of shading, especially in atlas cartography. A map user is not concerned about the method of performing shading on the map, but about the results. Photorelief has some specific traits, due to the passing from a three-dimensional model of relief to multi-tone photography, which plays the role of the shading original. An example of the application of this variety of shading is *Wenschow-Atlas für Höhere Lehranstalten* (1959). As it requires a very labour-consuming three-dimensional model and for other practical reasons this technique is chiefly suited to smaller scale maps, first of all atlas maps. Nevertheless, considering the visual qualities of this kind of shading and the fact that it has consistently been used on many maps, Wenschow should be recognized second only to Imhof in his contribution to the propagation of shading worldwide.

At present two fundamental factors influence the further development and dissemination of shading. They are the requirements posed by thematic maps and the technological progress in the production of ever more improved screens, photographic materials and cameras and all of the other equipment which enhances the quality and reliability of reproduction processes.

However, technological progress alone would not be enough to force the cartographies of many countries and cartographers themselves to reverse their sceptical attitude to shading. It was done by the spread of the map, which is nowadays considered one of the most effective and reliable means of conveying information.

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# AN ATTEMPT TO FORMALIZE GENERALIZATION OF HYDROGRAPHY

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The problem of generalization of hydrography is discussed extensively in cartographic and geographic literature. The reason seems to be twofold: firstly, the importance of rivers as an element of map content linked closely with many other components of natural environment and as one of basic resources used by man; secondly, a comparatively simple graphic form of cartographic presentation. Rivers are one of the more stable components of natural environment. They have been studied well and vast areas of the Earth have been mapped in detail. A map presentation of hydrography provides information about not only certain hydrographic features of the area but also about its landscape. Moreover, hydrography on a map serves as an orientation element.

The above facts indicate the necessity of a possibly accurate presentation of hydrography on maps. What is the reason for such large discrepancies in the picture of rivers, particularly on small and medium scale maps? Are those discrepancies an unavoidable attribute of a map resulting from the subjectivity of cartographic generalization? It does not seem so.

At present, more often than before, maps condition efficient work in many spheres of life. Thus, they must meet two basic requirements of praxiology: provide information in a possibly efficient and accurate way. Therefore, the map making process should be oriented more to the presentation of a vital problem of our times, i.e. the man-environment relation. In turn, the presentation of the river pattern should be formalized enough for the map maker not to waste time on repeated elaboration of it.

The many past attempts to formalize the generalization of hydrography on maps have brought us close to the solution of this problem. However, it seems difficult to solve the two basic problems of generalization, i.e. 'which streams should be presented' and 'how they should run'. Srnka's (1968) recurrent formula for stream selection, e.g., is based on indices which are not always accessible for larger areas. Fully and semi-automated systems for map elaboration (e.g., Oxford ECU, Cora 3, Wild EK 8 CRS, Konsberg Systems, etc.) also contain programmes for the generalization of hydrography. As the systems are usually designed for cadastral and topographic maps, they do not solve the problem of the generalization of hydrography in a coprehensive way. Thus, for instance, it is the map maker who performs the selection of streams in the semi--computerized (Cora 3) elaboration of the F.R.G. topographic map at the scale of 1:25 000.

The conclusion from the analysis of the to-date attempts to formalize

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the generalization of hydrography is that the problem should be solved in a way that is possibly simple, comprehensive and easy to digitalize; even if this was achieved at the cost of wiping out some hydrologic features in the picture of rivers.

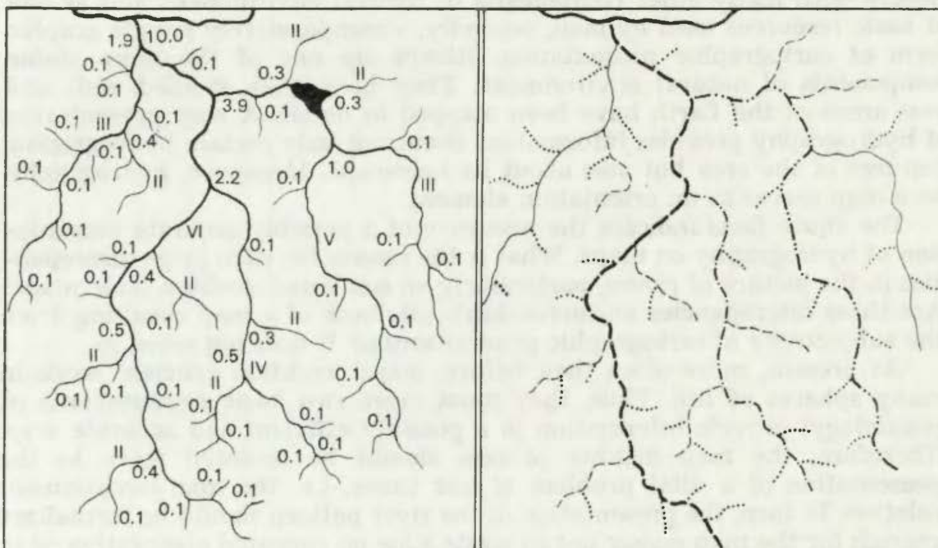
Such an attempt was carried out under the following assumptions:

1) The degree of the generalization of hydrography can be determined empirically on the basis of an analysis of the results of cartometric measurements.

2) Data for such an analysis can be obtained by measuring the lenght and number of streams on topographic maps at the scale sequence: 1:25 000, 1:100 000, 1:300 000, 1:500 000, 1:1 000 000, and 1:1 500 000.

3) Measurements should be repeated using different methods and on maps sheets covering a large, hydrologically diversified area.

Sheets of topographic maps and maps which are their generalizations covering some 65 000 km² of the area of South-East and East Poland were adopted as materials for measurements. The maps covered different geomorphologic and hydrologic areas: mountains, foothill valleys, uplands,




| length class | | value | designation on the map |
|---|---|---|---|
| 1 | bellow 2 km | 0,1 | |
| 2 | 2 – 5 | 0,3 | |
| 3 | 5 – 10 | 0,7 | |
| 4 | 10 – 15 | 1,2 | |
| 5 | 15 – 20 | 1,7 | |
| 6 | 20 – 30 | 2,5 | |
| 7 | 30 – 40 | 3,5 | |
| 8 | 40 – 50 | 4,5 | |
| 9 | 50 and more | | |

Fig. 1. An example of valorization of hydrography

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rises and ancient valleys. The picture of hydrography on the maps used for measurements dates back to 1930s, though some of the maps were published after the war (1:100 000, 1:500 000, 1:1 500 000). The length of all the streams was measured and their number was counted on 1:100 000 and smaller scale maps. Before the opisometer was used the length of a number of streams was measured using different methods: stepping, Penck's method and with an opisometer. Changes in lengths of those streams resulting from measurements employing different methods were presented on graphs. An analysis of the graphs showed that the results of measurements with the opisometer differ from the result of the other two measurements by a few per cent of stream length. As the results of measurements were classed by stream lengths, the accuracy of lengths measurements made with the opisometer was assumed to be sufficient. In order to save labour, streams were not measured on all the 1:25 000 map sheets but on selected samples of these maps (70 circles 400 cm$^2$ in area). Streams were also measured in corresponding circles on 1:100 000 map sheets. By comparing the results of measurement on 1:25 000 and 1:100 000 map samples the relation between the number and length of streams on those maps was determined. It was discovered that the 1:100 000 map presents 55 to 75 per cent fewer streams than the 1:25 000 map and those streams are by 35 to 45 per cent shorter.

The results of measurements of stream lengths on all the 1:100 000 map sheets and on smaller scale maps were classed according to stream length; mean values of those classes divided by 10 were taken as values of individual streams at ordinal scale (Fig. 1). A 1:100 000 map of hydrography was elaborated on the basis of the values adopted. On this map, lines of different shapes denote streams of adopted length classes; figures at stream confluences denote values of individual streams obtained by summing up the values of their tributaries, values of streams are a function of stream length and the number of their tributaries, i.e. river density in the basin of the given stream. The numbers of streams of equal values in particular length classes were counted on the map and tabulated.

The question 'how many streams' of the given length class should be presented on a map was answered by means of an analysis of stream number graphs on the maps at the adopted scale sequence (Fig. 2). These graphs indicate that 7 per cent of streams up to 2 km long which were marked on 1:1 000 000 map should be presented on 1:300 000 map; 35 per cent of streams 2 to 5 km long, 75 per cent of streams 5 to 10 km long, etc. should be plotted on the 1:300 000 map.

To answer the question 'which streams' should be presented, normative rules for stream selection were worked out on the basis of the table of values of streams and graphs of stream numbers. The principle adopted in this procedure was that the percentage of streams selected should include the streams of the biggest values.

The suggested method of stream selection is based in principle on the to-date selection criteria, but it formalizes this aspect of cartographic generalization of hydrography. Naturally it has its weak points. It assumes correct selection of streams on the analysed maps and the omission of all other than natural features of rivers, etc. It seems that if properly enhanced, this method could be used to elaborate value maps and keys to river selection in traditional or digital form, for individual countries or other areas.

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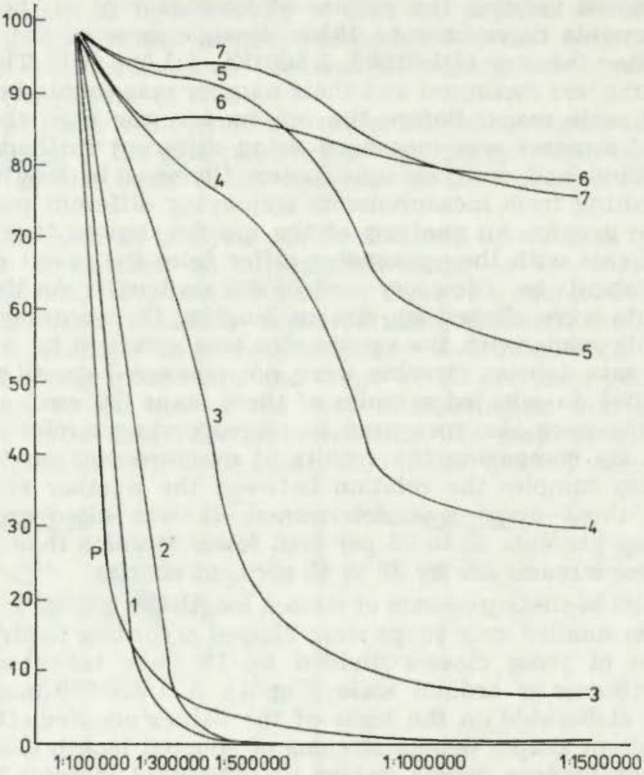


**Fig. 2. Changes in the number of streams selected for maps at different scales in per cent**

**1, ... 7 — stream length class, *P* — map area, Note: The area of 1 : 100 000 map equals 100**

It was suggested that stream shape generalization be based on the approximation of a broken line joining characteristic (extreme) points to the shape of stream line on the source map. The procedure is long following:

Spring and confluence, the two most important points of a stream, were joined with a straight line, which is the limit of stream shape generalization. All the other points of a stream together with characteristic points are usually outside the line, i.e. to the left or right of the line or its extension. The extreme point is the point on the stream line on each side of the straight line (or only one point on one side of the line) whose distance from the line is the biggest. When those points (or this point) are selected and connected with the points of spring and confluence, a broken linie is obtained, which is the generalized picture of shape of the stream. By way of selecting and appropriately linking successive pairs of extreme points, the picture of the stream step by step approximates to the presentation on the source map. When the extreme values of deviation (arrow) 'e' $\rightarrow$ 0, the two pictures become indentical (Fig. 3).

This method of line shape generalization is objective and relatively simple to be expressed in mathematical terms. Characteristic points, the so-called 'Sydow's similarity points', are faithfully presented in the picture

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of the stream shape. Undue simplification of small meanders may be eliminated by making 'e' value dependent not only on the reduction scale but also local coefficients of stream configuration.

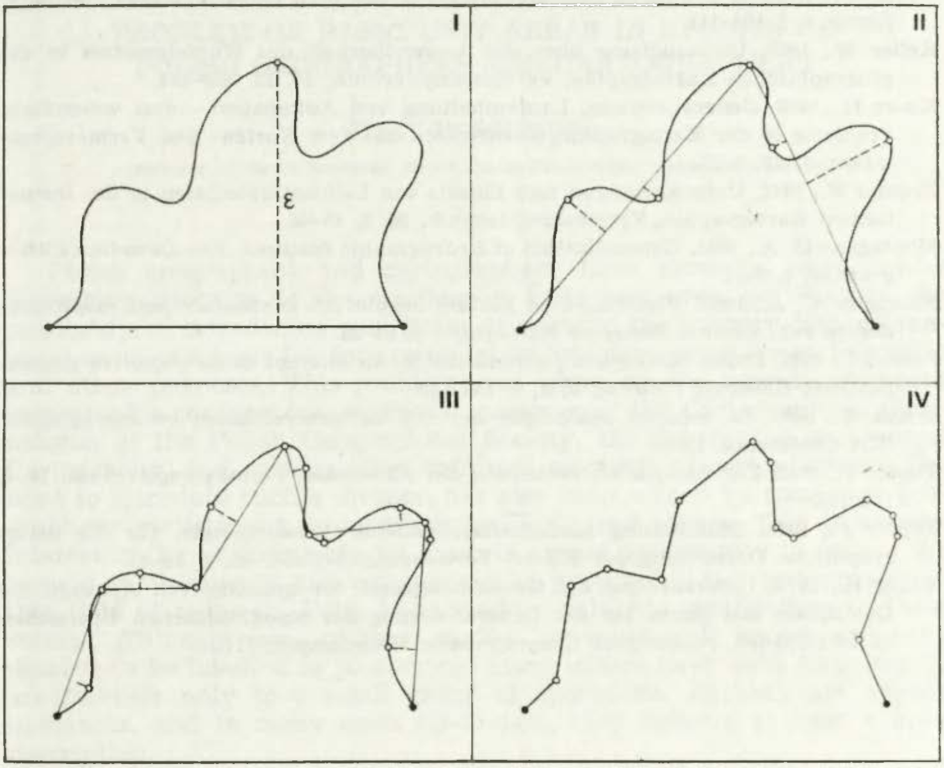


Fig. 3. An example of generalization of stream line
● — initial points (spring and confluence), ○ — extrem points, ε — extrem value of deviation

The described method of stream selection and generalization of their shapes was based on an analysis of hydrography presentations on maps of Poland. It can be also used in the process of elaborating reference maps for other areas of similar geographic conditions.

The 'novelty' of this method consists in the integration of two steps of generalization, i.e. selection and shape generalization. It is easy to be expressed in mathematical terms and it ensures quite accurate presentation of the geographical' character of the discussed phenomenon.

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# PROBLEM OF BASIC UNIT AREAS IN STUDIES OF POLISH GEOGRAPHERS AND CARTOGRAPHERS

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Polish geographers and cartographers have recently been paying increasing attention to the problem of basic unit area, particularly the possibility of introducing a uniform division of the country into geometrical units as a basis for data compilation and processing for cartographic and other purposes. This problem was often on the agenda of recent cartographic conferences, seminars, meetings of the Cartographical Commission of the Polish Geographical Society, the Committee on General Cartography, and various other informal meetings of cartographers. The need to introduce such a division has also been voiced by some non-geographers: statisticians, economists, botanists and others. This increasing interest in the problems of unit areas is a good opportunity to review the to-date achievements and experiences of geopraphy and cartography in this field of research. Poles have made a valuable contribution to these studies. Although some of their studies are quite well known and fully deserve to be labelled as pioneering, many others have been forgotten or are familiar only to a small group of specialists. As they are varied, numerous, and in many cases up-to-date, they deserve at least a brief description.

* * *

The first papers on some problems of basic unit areas, including geometrical units, were published mainly in German-speaking countries at the end of the 19th century.[1] Polish geographers raised the problem a little later. Sawicki (1910) is believed to be the first to have tackled the problem in his paper on the distribution of population in West Carpathian Mts. He was chiefly interested in the problem of basic unit selection. He analysed units of different types and criticized the division into administrative and geometrical units as artificial and physiographically and economically inconsistent. He finally endorsed the use of physiographic units as, in his opinion, factors influencing the distribution of the investigated phenomenon should be taken into account as early as in the selection of the basic unit. Like the vast majority of cartographers at that time, Sawicki did not pay too much attention to the problem of unit comparability with regard to their size and shape.

Romer (1910) showed more appreciation for the idea of unit comparability. He described the results of computations of relative altitude in

[1] Stöckl's study (1952) provides much information on the subject.

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areas delimited by geographical coordinate system of geographical graticule with sides of 1/2 degree (ca. 1800 $km^2$ in area). His studies covered a vast area of the then Polish territory. However, the results of computations were not presented in the form of a map but described only verbally.

Romer's work initiated further numerous applications of geometrical units to morphometric research in Poland. Czyżewski's work (1925) is one of them. He used units delimited by sections of meridians and parallels 2.5′ long (ca. 12.5 $km^2$) to elaborate a map of relative altitudes. Two years later, the same author published his study of the density of the Podolian valley system caried out on trapezium units of geographical graticule measuring 5′×5′ ca. 50 $km^2$ (Czyżewski 1927). At the same time Czekańska (1927) made a map of relative depths of the South Baltic using geographical graticule units measuring 10′×10′, and Ochocka (1927, 1931) elaborated the first map of relative altitudes for the whole Poland basing on a trapezium network measuring $\Delta\lambda = 15'$ and $\Delta\varphi = 10'$ (ca 100 $km^2$).

Alongside trapezium units which to some extent varied in size and shape, geometrical units separated from geographical graticule were also used. Kubijowicz's work (1928) is an example of that. He used a grid of 16 $km^2$ squares to elaborate a map of relative altitudes of Eastern Beskids. Czort and Sarnicki (1929), Gajda (1929), Malicki (1934) and others also used square units to compute relative altitudes. It is worth emphasizing that Malicki used them to make a map of relative altitudes for the whole earth.

Geometrical unit networks also came to be used, although less frequently, for the elaboration of maps presenting economic and population phenomena. The following maps were made with their help: a map of population density of the Polesie region (100 $km^2$ squares) by Kubijowicz (1926), a map of the distribution of post offices and post office traffic in Kraków voivodship (56 $km^2$ squares) by Ormicka (1926), a map of surfaced roads density in Poland (trapezia with sides $\lambda = 15'$ and $\varphi = 10'$, ca. 300 $km^2$ in area) by Turczański (1928), a map of population density in Wołyń (100 $km^2$ squares) by Kulicki (1929), a map of settlement dispersion in Podole (trapezia with sides $\lambda = 5'$ and $\varphi = 2.5'$) by Lisikiewiczówna (1934) and other maps.

The above list of the applications of geometrical unit networks is not complete but it is a sufficient proof that the idea of comparability of basic units was quite early accepted by many Polish geographers.

Uhorczak's (1930) and Czekalski's (1933, 1934a, b) works on the isopleth method, at that time widely used in Poland for the presentation of the so-called 'discontinuous phenomena', notably advanced the study of basic units. In these works, both authors investigated basic units from the viewpoint of the requirements of interpolation.

Uhorczak proved that interpolation axes linking control points of contiguous units cannot intersect or form tetragons, as in such cases there are two possibilities of determining the shape of isolines (Fig. 1). He also noted that a prerequisite for avoiding this interpolation ambiguity is to arrange interpolation axes triangularly; this can be achieved by an appriopriate shifting of units (Fig. 2) or by the use of a unit network with automatically satisfies this requirement (e.g. a hexahedron network).

It was only 20 years later that the results of Uhorczak's studies gained more recognition. Nowadays they are quite commonly accepted in the world and quoted in nearly all cartography text-books which, however, often fail to give the source. Later, Mackay (1953) and others proposed

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different solutions for avoiding the ambiguity of interpolation, which did not require a triangular arrangement of interpolation axes. However, they do not diminish the value of Uhorczak's method as they violate the simple principle of determining isopleths on the basis of strictly mathematical linear interpolation.

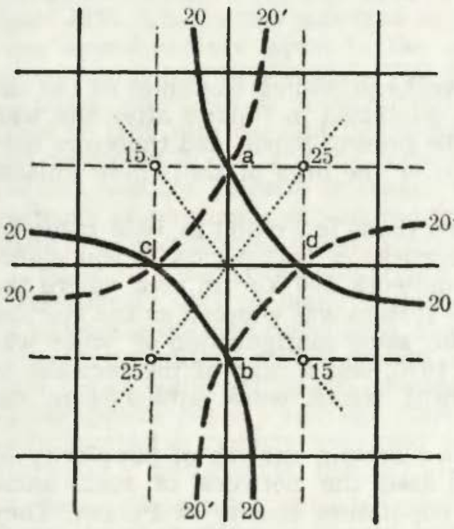


Fig. 1. Two variants of isoline shape under tetragon arrangement of interpolation axes (after Uhorczak)

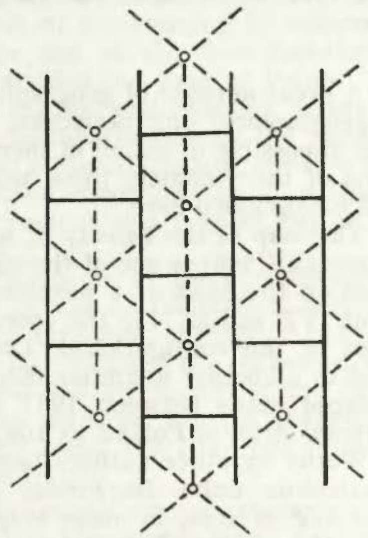

Fig. 2. Triangular arrangement of interpolation axes resulting from unit shift (after Uhorczak)

Starting from an analysis of the specific requirements of the isopleth method, Czekalski defined a number of conditions which should be satisfied by correctly constructed basic unit networks. In brief, they are the following:

a) a unit network should be compact, i.e. it should cover the studied area without gaps or overlapping,[2]

b) units should be fully comparable in respect to shape and size,

c) the shape of units should be as close as possible to the circle,

d) the shape and arrangement of units in the network should allow for preserving constant lengths of interpolation axes and a constant angle between axes converging in control points.

The above conditions are best satisfied by hexahedron unit networks, whose advantages were strongly emphasized by Czekalski.

Of works published in the inter-war period Strada's work (1931) on methodological problems of morphometric studies is worth mentioning. He emphasized the advantages of geometrical units and stressed the need for a unification of their networks by way of establishing initial lines of division and prescribing the size of units for morphometric studies. The limiting of accidential overlay of unit networks is the most interesting of his proposals. Strada noted that the results of calculations and in conse-

[2] This condition is sometimes broken. That is the case when the method of the so-called 'moving unit area', most often in the shape of a circle, is employed. See relevant remarks on the subject in Moscibroda's article (1980).

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quence the image of a phenomenon vary as the method of overlaying units in the studied area is changed. In order to make these images uniform, he suggests a correction of the shape of isopleths on a map on the basis of data determined for the other, opposing unit overlay, i.e. vertically and horizontally shifted by half the length of unit sides. This idea was not resumed and fully developed in Poland until thirty years later.

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A great number of geographical works providing examples of the use of geographical unit networks, were published in Poland after the war. It is impossible to list all of them in the present paper, and therefore only some of them namely those which cover the area of the whole Poland, will be discussed here.

The map of the density of surfaced roads in Poland in 1939 made by Uhorczak (1948) is one of the earliest works of that period. It was elaborated on the basis of a hexahedron network 100 km² in area where the point 19°E and 52°N in the coordinate system was adopted as the starting point of the configuration. Later, the same configuration of units was used to elaborate a similar map for 1970, and a map of the increase in surfaced roads between 1937 and 1970, which were published in the *National Atlas of Poland* (p. 106).

Works by other authors testify to a certain growth of popularity of hexahedron units. Barwińska (1963) used the network of such units, 1000 km² in area, to make maps of population density in Poland. They were also used in Dziewoński and Kosiński's work (1964), where hexanedrons with sizes identical to the ones used in Uhorczak's works were used to analyse changes in population distribution in Poland.

There are also numerous examples of applications of other types of geometrical units, mainly trapezium units of geographical graticule and a grid of squares. They include Czyzewski's map (1949) of mean altitudes in Poland elaborated on the basis of 15'×15' trapezia, Piasecki's map (1949) of relative altitudes in Poland based on 100 km² squares a more recent map by Dębowska on the same subject elaborated on the basis of squares about 36 km² in area published in the *National Atlas of Poland* (p. 18).

Many Polish undertakings in the field of basic units are connected with Professor Franciszek Uhorczak's work. For many years he has been an indefatigable propagator of the idea fo comparable units. He had written many papers and inspired his students and associates to conduct similar studies and works. Many specimens of those works collected in the Cartographic Department of the Maria Curie-Skłodowska University in Lublin have repeatedly been displayed and discussed at different cartographic and other conferences, but a substantial part of them has not been published yet. Therefore they deserve at least a brief description.

Shortly after the war, Uhorczak initiated one of the methods of the construction of a basic unit network which consisted in determining areas of approximately the same sizes by means of linking small administrative units. Naturally, units obtained in this way vary in shape, but as they are little different in area they satisfy well the requirement of comparability in respect to size. Moreover, they have another valuable advantage: as they are linked with the administrative division they greatly facilitate the obtaining and computing of exact data for different pheno-

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mena on the basis of easily accessible publications of statistical offices. Recognizing the advantages of this method, Uhorczak used it to elaborate several networks of division into units for the area of all Poland and for former Lublin voivodship. The earliest divisions worked out for Poland were the divisions into the so-called average voivodships and physiographic-administrative regions, both of them based on the districts (poviats) from 1952. The former emerged as a result of determining 17 units with area approximately equal to the average size of the then functioning voivoidships (ca. 18 377 km²). The later divided the area of Poland into 31 units with area of about 10 000 km² (10 056 km² exactly). Uhorczak tried to take into account physiographic boundaries (hence the name of the divisions) in determining those units, i.e. he attempted to distinguish regions possibly uniform in regard to natural conditions. Later, a similar network of physiographic-administrative regions was worked out on the basis of administrative division from 1956.

Basic unit networks elaborated in the course of these studies were subsequently used in many cartographic studies on population, economy or physical geography problems; the isopleth method, choropleth map and diagram presentation were applied. Uhorczak discussed the earliest studies in a paper delivered at the meeting of the Lublin Branch of the Polish Geographical Society in 1952. One of his divisions into physiographic--administrative regions was used later by Jedut (1961) in his study on Uhorczak's cartographic method of concentration.

Later, Uhorczak inspired Kozłowski to launch similar attempts. They were aimed at dividing Poland into smaller size units. First, Kozłowski worked out 4 variants of division into 100 units with the area of some 3120 km² basing on the 1960 network of poviats. Individual variants differed in the method of the grouping of districts; one of them was aimed at determining units of minimum deviation from the assumed size, whereas the aim of others was to arrive at possibly compact shape or to embrace physiographic factors. Subsequently Kozłowski divided Poland into 624 units of some 500 km² in area basing on the rural district and town network from 1960. The division was constructed so that by means of direct linking of units one could arrive at higher rank divisions into, e.g., 312 units of some 1000 km² in area, 208 units of some 1500 km² in area, 156 units of some 2000 km² in area, etc. In this way within one division it was possible to pass to a description of divisions on a higher level of generalization. The findings were presented at the 1st All-Polish Cartographic Conference in Lublin in 1968, and published in part in the proceedings of this conference (Kozłowski 1971). Regrettably, the practical application of those methodologically valuable studies was nullified by the reform of administrative division.

Only one division of Poland into similar size units has so far been worked out on the basis of the present (since 1975) administrative division. It was performed by Uhorczak, who distinguished 49 units, which like the first work of this type can be denoted as 'average voivodships'.

Apart from the above listed divisions of Poland, similar networks were made for other countries and then continents. Most of them were made as M.Sc. theses supervised by Uhorczak in the Cartographic Department of the Maria Curie-Skłodowska University in Lublin. Relevant administrative and political maps and accessible statistical sources were used for this purpose. Those divisions were afterwards used in the elaboration

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of maps of population density. The studies were crowned with an isoline map of world population density made on the basis of units about 300 000 km² in area, i.e. corresponding to the size of the Polish territory.[3]

The fact that Uhorczak widely used the method of administrative units of similar sizes does not mean that he abandoned the use of a geometrical unit networks. Whenever it was possible to compute relevant data for them, he continued to use this type of units in different studies of both small regions and large areas going beyond Polish borders. Thus, he supervised another series of M.Sc. theses similar to the above mentioned, whose authors elaborated maps of population density of continents and then the world on the basis of hexahedron units of some 100 000 km² in area. Presumably the first map of world population density elaborated on the basis of geometrical units was the crop of these studies.

Alongside his experiments with geometrical units for individual continents, Uhorczak engaged in the elaboration a uniform network of such units for the whole world. The target was to work out a basis providing for the making of correct maps of measurable features of continuous-occurrence phenomena (e.g. relief, climate etc.). Uhorczak first attempted to reach this target already in the 1930s but he did not elaborate the ultimate assumptions of three variants of such a division until 1952. The principle of their construction is simple and consists in determining equal area trapezium units within latitude zones of appropriately selected widths. One of those variants, recognized as the best, was used by Moscibroda (1971a, b) to elaborate a map of relative altitudes of the earth's crust. He divided the earth into 510 units 1 000 000 km² in area. Units distinguished in successive zones were shifted in relation of each other to enable unambiguous interpolation in the elaboration of isoline maps. A network of these units is supplied with an index of geographical coordinates of all the lines which make up its construction. Within the framework of this division it is possible to determine trapezium units of smaller sizes; such studies have already been launched.[4]

Uhorczak also inspired studies aiming at the definition of the role of the network of basic units in the shaping of the picture of a phenomenon on maps which were made on the basis of these units. They include Barwińska's studies (1963, 1968) and Moscibroda's later studies (1976, 1978).

Barwińska should be commended for having resumed and elaborated the idea of repeated overlay of geometrical unit networks proposed by Strada in the inter-war period. Analysing the problems she defined practical rules for shifting unit networks in successive overlays (Fig. 3). She suggested that the values computed for individual overlays of units should be treated as one whole and considered as moving averages, which can be referred to a network of control points multiplied by the number of unit overlays. Those values can be used as a basis for the elaboration of an isoline map which would be largely free of accidental overlay of units networks (Fig. 4). Maps elaborated in this way make a sound basis for precise studies of the dynamics of a phenomenon in space and time.

[3] This map was elaborated by Grzechnik; it is enclosed to this volume of *Geographia Polonica* (cf. Uhorczak *et al.*).

[4] This study is being carried out by Kardaszewska in the Department of Physical Geography of the Maria Curie-Skłodowska University in Lublin.

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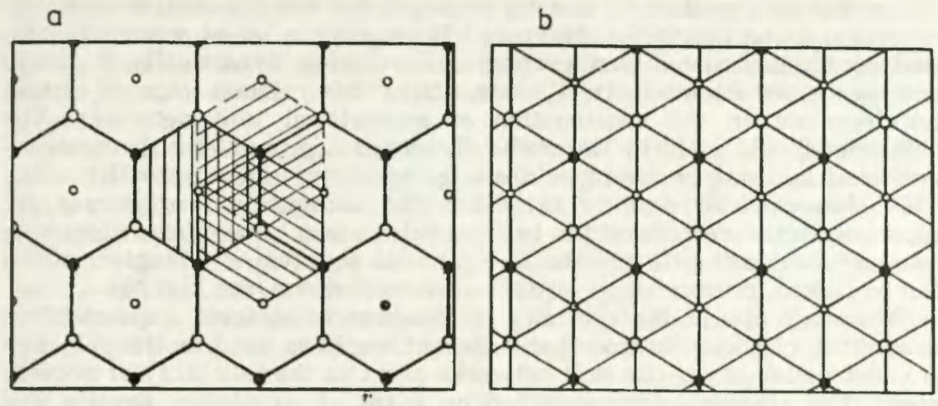


Fig. 3a. Distribution of control points and method of unit network shift when there are three overlays (exemplified by shift of single unit). 3b. Network of interpolation axes when there are three overlays of unit network (after Barwinska)

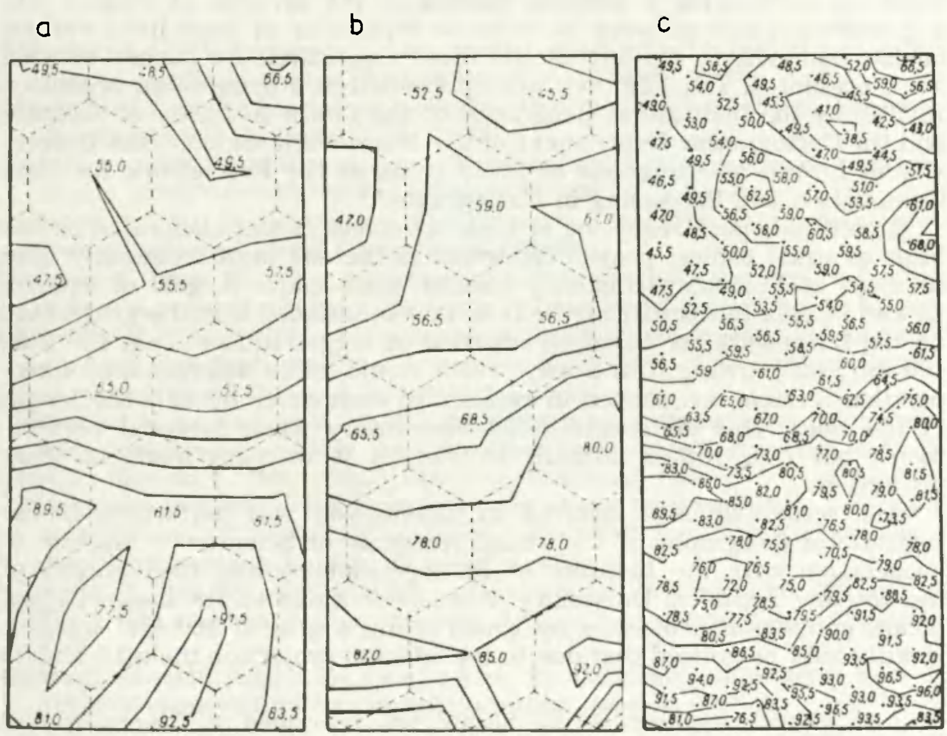


Fig. 4. Samples of isoline maps obtained by way of: a and b — one overlay of unit network, c — twelve overlays of unit network (after Barwińska)

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Barwińska's method of moving averages has not yet been extensively described in cartographic literature.[5] It requires a lot of work but now that computer-assisted cartography is developing dynamically it surely deserves more attention. It is worth noting this method imposes certain requirements on the construction of geometrical unit networks. The networks should yield to hierarchic division, i.e. provide for the determination of adequately arranged units by means of linking smaller units. This characteristic notably simplifies the computation of values for successive unit overlays on the basis of values which have been determined once for small primary units, e.g. small squares or triangles, which can be linked to form bigger squares or hexahedrons (see Fig. 3b).

The main aim of Mościbroda's studies was to perform a quantitative evaluation of the influence that different methods used in the selection or construction of regular unit networks exert on the reliability of isopleth maps. The studies were conducted on maps of population density and mainly consisted in controlling the so-called statistical rationality. The results of measurements showed that features of basic units essentially condition the picture of a phenomenon on a map and determine its cartometric properties. They generally confirmed the advantages of geometrical units. They also provided for ascertaining the extent of the negative effects of networks of those units which do not satisfy the condition of full comparability or regularity; in extreme cases (e.g. administrative units) those consequences are enormous.

As it has been stressed early in the paper, more and more cartographers insist on introducing a uniform system of the division of Poland into a geometrical unit network in order to replace or at least limit various *ad hoc* methods. In the last decade three suggestions for such a division were presented. The first two were presented at a symposium organized in 1976 by the Institute of Geography of the Polish Academy of Sciences and the Cartographic Department of the Maria Curie-Skłodowska University in Lublin on 'Problems of Basic Units as the Framework for Data Compilation and Processing in Cartography'.[6]

Mościbroda performed one of these divisions. It was elaborated on the basis of equal conical projection, which is the one most frequently used in maps of Poland, particularly smaller scale maps. A grid of squares 25 $km^2$ in area forms its construction. It was assumed that the grid would be the framework for the determination of bigger squares (e.g. 100 $km^2$, 400 $km^2$, etc.) arranged in a way which would make unambiquous interpolation feasible, i.e. shifted in relation to each other by half the length of the sides. This division satisfies elementary methodological requirements but it is rather difficult to transfer it to maps made in other projections.

The second division inspired by Dziewoński was performed in the Institute of Geography of the Polish Academy of Sciences in Warsaw in cooperation with the Institute of Photogrammetry and Cartography of the Warsaw Technical University. It was elaborated on the basis of equal secant cylindrical projection by constructing a grid of 100 $km^2$ squares. It will easily be noticed that due to the adopted projection the grid divides

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[5] An identical approach to this method was later used by Chervyakov and Yulinov (1975).

[6] See the report of this symposium in *Polski Przegląd Kartograficzny*, 4, 1972, 3, 139–140.

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the area of Poland into equal area spherical trapezia—flattened in the south and elongated in the north of the country. Thus, in order to preserve a constant shape of units it is necessary to use cylindrical projection, which in turn entails quite noticeable deformation of the picture of Poland on a map.[7]

Podlacha (1980) suggested the third division of Poland into geometrical units. The construction of this grid was also based on geographical coordinate system but, as opposed to the division described earlier, sides of the distinguished units (trapezia) had constant angles. Such a solution results in certain fluctuations of unit sizes. The grid is of a hierarchical character and the smallest trapezium is of some 6.25 ha in area.

The above presented description shows that each network has some advantages but unfortunately its disadvantages cannot be fully eliminated.

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In the present paper the author has presented quite an extensive list of studies of Polish geographers and cartographers on the problems of basic unit areas. Emphasis was put on the diversity of these studies but not all of them were described at length, particularly as concerns the uses of geometrical unit networks. The author hopes this paper will elucidate the contribution of Poles to this field of research and that will add to the knowledge of basic unit area.

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[7] A detailed description of the principles of this division is provided in the paper by Dziewoński et al. (1974).

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# REFLECTIONS ON CHOROPLETH PRESENTATION AS A MAP OF REGIONAL ATLAS

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First geographical atlases were map collections which could be called reference maps today. In time, however, the content of atlases was extended to cover physical and socio-economic problems and this required the introduction of maps of other types and different methods of presentation. Choropleth mapping, applied in nearly half of the maps of the National Atlas of Poland, is one of the more frequently used methods of presentation, often alongside other methods. In seven Polish regional atlases the share of this method of presentation ranges from 36% (in the atlases of Opole and Katowice voivodships) to 69% in the atlas of Zielona Góra voivodship.

Apart from the fact that it appears easy to elaborate a choropleth map, such a relatively high share of choropleth presentation in atlases results also from the fact that in comparison with reference maps these maps can be reduced many times in relation to basic scale maps. As a result comparatively many themes are usually presented on one atlas page, which can contain 4, 9, 6, 12 or even 16 choropleth maps.

Phrases like 'common cartographic manner', 'common cartographic means', 'overall design principles' etc. are used to describe a geographical atlas. 'Those groups of phrases describe not only the selection and arrangement of the maps of atlases but also the mutual consistency and complementary character of the content as well as the uniformity of the used methods of cartographic presentation depending on the scope and kind of an author's intentions' (Horodyski 1979, p. 90). The above listed features manifest themselves in the making of uniform explanatory keys to reference maps of an atlas. Apart from common explanatory keys to the maps covering different areas, the authors take a number of assumptions — usually unknown to an atlas user. The generalization level of hydrography, settlements, relief, etc. are determined. The aim of such a coordination is to achieve a comparable picture of different areas. The point is for the maps of the atlas to provide comparable information about spatial differentiation of hydrography or settlements. The comparability of thematic presentations, e.g. geological maps is essential, too. It is possible only when maps covering different areas such as continents have been made according to the same classification criteria and the degree of generalization of the content.

According to Horodyski (1979), the essential feature of a geographical atlas as a map collection is their combined effect resulting from the so-called secondary function which is defined as dependences between

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multi-thematic maps referring to the same area. This is the function which is characteristic of national and regional atlases.[1]

Regional atlases represent precisely defined geographical areas. Different elements of those areas investigated in geographical studies are interrelated in various ways. An atlas should provide possibly complete information about the area to the extent defined by its authors, i.e. it should present different interrelations. In cartography, this requirement is tantamount to the elaboration of comparable maps. It is obvious that geomorphology depends on geological structure and vegetation cover on soil. Aware of these interrelations a map author has to choose a proper method of elaborating these maps. The elaboration of the maps of physical phenomena has quite a long tradition and the relations between elements have been studied well. However, it also seems that with regard to socio-economic elements presented in a more 'statistical' way both the map making tradition and the knowledge of relations which can be represented cartographically are remarkably poorer. Moreover, there are a number of relations of which a map maker is not aware and those are relations frequently unknown to geographers, too. In order to design the maps of an atlas one must realize that they may not present a state of knowledge only, but they should be a record allowing for a further study of an area. One of the basic operations of such a study is the comparison of the distribution and intensity of geographical phenomena. One should examine statistical description of socio-economic space with regard to their best possible utilization to see whether multi-thematic maps of the same area are comparable.

While in the case of mono-thematic map collections comparability means the *comparability of areas* in respect to certain features, in regional and national atlases it means *the comparability of content* in the same area.

The subject of further discussion is the method of choropleth mapping, so often used in regional atlases to present socio-economic problems.

* * *

To make a choropleth map it is necessary to have:
1. A map containing boundaries of spatial units
2. Statistical data relative to them.

1. Assuming the comparability of a choropleth map as a starting point for further discussion, it is understandable that identical spatial division and data relative to the same period (decade, year, month) or a point in time (for instance 31, Dec., 1982) must be used.

In geography to accept a certain spatial division is tantamount to accept a certain scale of a study. Thus, referring to a choropleth map, the term *scale of presentation* may be used, as the traditional concept of the scale (the ratio of reduction of linear elements) is not so important in this method of presentation, as it is in the case of reference maps. The adoption of a certain scale of presentation should be a decision of an essential geographic character for it influences not only the degree of detail of presentation but also the relations between the presented subjects.

[1] It should be explained that according to the quoted author the dependence or, in other words, the basic function occurs in the case of map collection representing *different areas*.

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It does not seem, however, that the traget is to use an identical scale of presentation for all the subjects. This results from the nature of geographical phenomena which are described through systems of spatial units with different degree of aggregation. Therefore, the so-called computer atlases published so far contain incomplete characteristics of areas as they employ only one level of data aggregation. Poland, for instance, is divided into two administrative levels: 49 voivodships with area from 12 300 $km^2$ to 1500 $km^2$ and 2873 second level units i.e. rural districts and towns with 108 $km^2$ average area. Therefore, it would not make sense to describe all the phenomena on one of those levels only. While the presentation of population density on the level of small units gives quite an interesting picture, the presentation of such subjects as 'beds in hospitals per 10 000 persons' or 'seats in cinemas per 1000 inhabitants' [2] in reference to rural districts would not make sense, for the range within which those institutions work goes beyond the boundaries of the second level of administrative units. For such subjects a meaningful picture is not achieved below the level of a voivodship.

However, the application of different spatial units should be a considerate decision suggesting to the user that there are certain relations within a group of choropleth maps at a given scale.

Nevertheless, it seems that the application of different scale of presentations in choropleth maps in regional atlases is a result of data accessibility rather than the author's deliberate decision.

2. The method of processing of statistical data to be presented in a choropleth method is another problem. It consists in a class selection i.e. the construction of a distibution series. Before the data are processed, the following are usually considered:

— the number of intervals

— the limits of intervals

Several methods of class intervals selection of different properties have been elaborated. In some of those techniques the number of classes results from statistical distribution and is difficult to predict. However, most methods of class interval selection require an advance decision on a certain number of intervals. In practice, 4 to 10 classes are employed in atlas choropleth maps. Choropleth maps with 2 or 3 classes are just as infrequent as choropleth maps with more than 10 classes.

As it has been already mentioned, metric scale of a choropleth map is not so important as the scale of reference maps. A choropleth map can be enlarged and reduced to the limits of legibility and there is no such thing as content saturation adequate for the given scale. That is the reason why some cartographers do not consider a choropleth map a map in the proper sense of the word. It is worth noting that Jenks associates the number of classes of a choropleth map with generalization. He uses the term '5 class generalization' (Jenks and Caspall 1971) applying one of the basic cartographic terms in reference to the choropleth map as a statistical construction where the concept of the scale cannot be used effectively. It seems to be a very accurate term, for it allows choropleth map differentiation with the omission of metric scale.

In the light of the above discussion it is evident that a prerequisite for comparability of choropleth maps is adherence to a uniform level of

[2] These are subjects from the *National Atlas of Poland.*

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generalization i.e. the number of classes and to a uniform scale of presentation i.e. the reference of the content to uniform spatial divisions.[3]

* * *

The comparison of choropleth maps can be understood as an 'overlapping' of their contents to discover spatial relations between the subjects compared. Let us assume that two sets of data representing two subjects have been divided into two parts, each of which has been marked on the map (Fig. 1). The classes marked on the maps of area will be denoted as $A+$ and $A-$ distributions of $A$ phenomenon and $b+$ and $b-$ of $b$ phenomenon. By comparison of the two choropleth maps, four types of areas can be distinguished $A-\ b+$, $A-\ b-$, $A+\ b+$, $A+\ b-$, which can be characterized in terms of intensity of $A$ and $b$ features. Naturally, the number of classes ($n$) can be increased and then the number of two-feature areas can amount to $n^2$. In this situation, the determination of relations between the distribution of different phenomena is the principal goal of comparing maps.

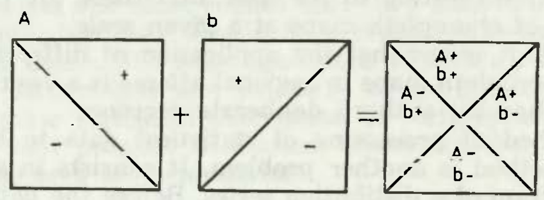


Fig. 1

Such comparisons, and above all their interpretations, are purposeful assuming that the distinguished classes of different phenomena are comparable. In other words, the point is to perform such divisions of statistical sets that the distribution series arrived at could be considered as elaborated according to one uniform, sensible rule; this is, in my opinion, a problem of statistical rather than cartographic nature.

When a definite number of classes for the compared choropleth maps is adopted the following two issues should be considered:

— class range, or rather the sequence of ranges

— class frequency i.e. the number of spatial units in each class.

When elaborating a choropleth map, attention is paid to the sequence of class ranges (constant, increasing, decreasing), a more detailed description of which can be found in a well-known textbook *Elements of Cartography* (Robinson, Sale, and Morrison 1978). When adopting a principle of interval construction for choropleth maps compared, it makes to treat one of the above mentioned elements as constant i.e. a uniform rule of class range or a uniform frequency of classes. It is virtually impossible to preserve both features of the set at the same time and it can be assumed that they are mutually exclusive features. This problem is illustrated in Fig. 2, where $r$ means interval range and $i$ means

[3] The present paper presents neither the problem of comparability of systems of spatial units nor the problem of indexes used as those issues go beyond choroplethic presentation and have been quite well discussed in the literature.

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class frequency. Figure 2A shows sets of different distribution which, however, does not significantly influence the range of intervals as they have been selected on the basis of two extreme values, marked with asterisks. It is clear that the adoption of a uniform principle for the selection of intervals of an increasing or decreasing range for a larger number of sets (subjects) may be in evident discord with their statistical distribution (cf. Jenks and Coulson 1963).

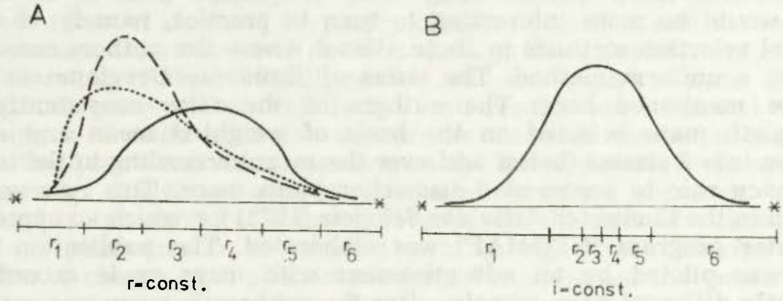


Fig. 2

In Fig. 2B the principle of uniform interval frequency has been adopted, which obviously results in different interval range. It is only owing to the fact that normal distribution has been adopted for an illustration that there is a certain regularity of ranges; that, however, rarely happens in geographical studies. It is worth adding that this division i.e. division into uniform frequency classes is virtually always feasible and the only limitation may be too small set frequency.

Two main trends may be distinguished among the methods of class interval selection of a choropleth map:

— the construction of identical or similar frequency intervals (cf. Jenks and Coulson 1963; Evans 1977),

— optimization of interval selection so that the value of differences in a given class are possibly the smallest whereas the differences between the intervals are the largest. Depending on the definition of similarity, a number of interval selection technics have been worked out (e.g. Jenks and Caspall 1971; Tikunov 1980). This trend pursued in the last decade mainly by American cartographers results in choropleth maps of different range and class frequency, which is a reflection of statistical data distribution, and in some techniques it depends on spatial arrangement of units (Monmonier 1972; Pasławski 1982).

The first trend is interesting for further discussion as it is convergent in its assumption with the feature of uniform class frequency (cf. Fig. 2B). The idea of such a construction of the distribution series for cartography that frequency of the established classes is identical or similar probably originated simultaneously with the so-called statistical cartography. When examining choropleth maps made with the help of 'traditional' methods, it will be observed that in by far most cases class range increases with the increase of statistical values. Mackay's (1963) studies can be quoted here. Although they mainly concern isopleth presentation, they reveal an increase of interval range, which naturally suggests that skewed

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distribution occurs. Increasing intervals of hypsometric maps are an analogy understandable to every cartographer.

Thus, one is let to believe that in search of a 'comparable' class interval selection method, methods ensuring identical or similar class frequency should be considered in a more detailed way.

One might now proceed to review appropriate methods, but that seems unnecessary as such lists, though not always complete, are easily accessible records (e.g. Kishimoto 1972; Evans 1977; Robinson, Sale and Morrison 1978).

It would be more interesting to turn to practice, namely to discuss interval selection methods in those atlases where the authors consciously applied a uniform method. The *Atlas of Economic Development* (1961) can be mentioned here. The authors of the atlas consistently used choropleth maps selected on the basis of weighted mean and applied division into 3 classes (below and over the mean) according to the uniform frequency rule to arrive at 6-class choropleth maps. This rule was also applied in the *Computer Atlas der Schweiz* (1972) for which an appropriate computer program (GEOMAP) was elaborated. The publication of the atlas was piloted by an advertisement with maps made according to a slightly different rule, namely, after the arithmetic mean was computed identical range classes were selected.

The problem of the construction of choropleth maps of comparable class intervals was closer described by Armstrong (1969) who proposed set division according to the following procedure:

a) compute the mean,

b) compute standard deviation ($\delta$),

c) select class ranges as a part of standard deviation. Depending on the required interval number, parts of deviation are adopted in such a way that assuming normal data distribution particular classes comprise identical number of observations (cf. Fig. 2B).

This division was applied by Armstrong (1969) on the maps of the mortality in the USA. According to the author, who described at great length the problem of proper index choice for the presentation of those subjects, this method of data division into classes is adequate in the case of map comparison. Standard deviation can be treated as a common measure for different sets. This method has a number of advantages but its disadvantage is that it can be correctly used only in normal set distribution. Evans (1977) pointed to this drawback and gave tables providing for an easy computation of intervals with theoretically the same number of observations.

A method of division, similar to the above presented, can be found in the Belgian *Atlas du Survey National* (1970). Ten classes were employed in all the choropleth maps and their range was selected as a multiply of standard deviation computed for each subject. Although the advantages of standard deviation as a measure allowing a definition of the position of every areal unit in the data set were emphasized in the preface, the authors of the atlas were not consistent when they used intervals of different range and frequency. Therefore, to say that an areal unit is in the third class on both maps does not mean that its position is identical in both statistical sets. No larger experimental studies have been conducted yet and of those carried out so far Olson's study (1972a, 1972b)

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should be mentioned. In the first experiment, the author employed 4 methods (in 8 versions) of dividing computer-generated statistical sets with normal distribution. First, product — moment correlation coefficient $r$ between respective statistical sets was computed and next Kendall's rank correlation $t$ was computed on the basis of distribution series (of maps) with different class numbers. It turned out that the similarity of product — moment correlation coefficient decreases, alongside the decrease of set frequency and a decrease of number of class. As concerns the methods of division employed, quite good results were achieved on choropleth maps of identical frequency classes (quantiles) and the 'nested means' division i.e. a two-level division through the calculation of means. The other study (Olson 1972b) carried out on empirical data (96 000 observations) proved that relatively best results are achieved when performing a division with the use of the standard deviation method, whereas the quantile division was low on the list of the methods applied.

Monmonier (1976) presented quite an interesting approach to the problem of comparability of choropleth maps. On the basis of a choropleth map of $A$ phenomenon he worked out an algorithm allowing such a selection of classes of $B$ phenomenon which maximized the possibilities for determining visual correspondence on both maps. Despite the fact that a variety of different experiments have been conducted, authors are cautious to evaluate their results because of the number of unsolved problems and the fragmentary character of studies. Doubts arise whether investigation of large statistical sets to obtain 'mean' results is the proper way to find the best method of class interval selection. The discovery of the statistically best method does not guarantee that it will not turn out utterly inadequate for at least a few maps. The application of such a system excludes the possibility of comparisons. When the perception abilities of users of this type of maps are considered, the correctness of indexes used at calculations is equally disputable.

It can be expected that atlases with formalized class interval systems employing computer assisted cartography will continue to appear. In cartographers' opinion these atlases constitute a separate group — quite remote from 'traditional' regional and national atlases. The rather traditional approach to the elaboration of cartographical works of this type is surprising. After all, one should strive to use the experience resulting from the rather formal approach to choropleth presentation imposed by the properties of computer assisted cartography; nevertheless it would notably increase the possibilities of cartographic experiment.

Authors should spare no effort to elaborate fully comparable maps, and choropleth maps are only one of the presentation methods. A conscious acceptance of the principle of choropleth map comparability by, among others, establishing a common principle of class interval selection, practically calls for abandoning the so-called *round numbers* (e.g. 10, 15, 100 etc.). This decision would be extremely difficult for many cartographers as a remarkable majority of classes — not only in choropleth map — are selected in this way. Naturally, the purpose of an atlas is of some significance, too.

For the time being, nothing augurs a revolution in the field of the elaboration of atlas maps. This situation results chiefly from the fact that we cannot substitute the present tradition with a new, generally accepted method of class intervals selection. Moreover, we seem not to be sure

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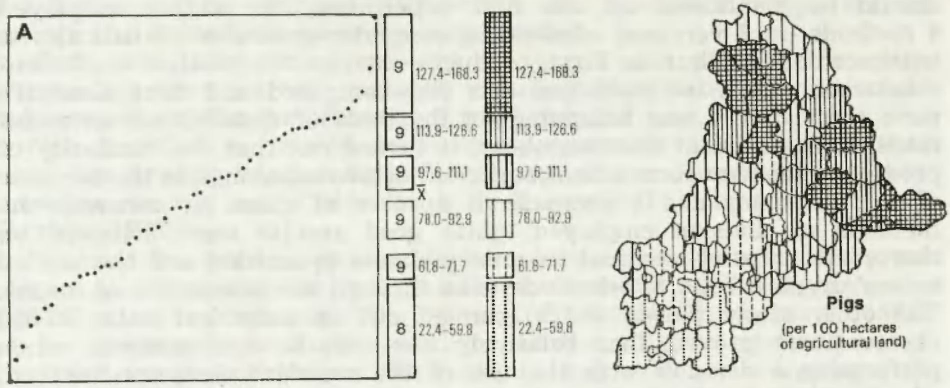


Fig. 3A

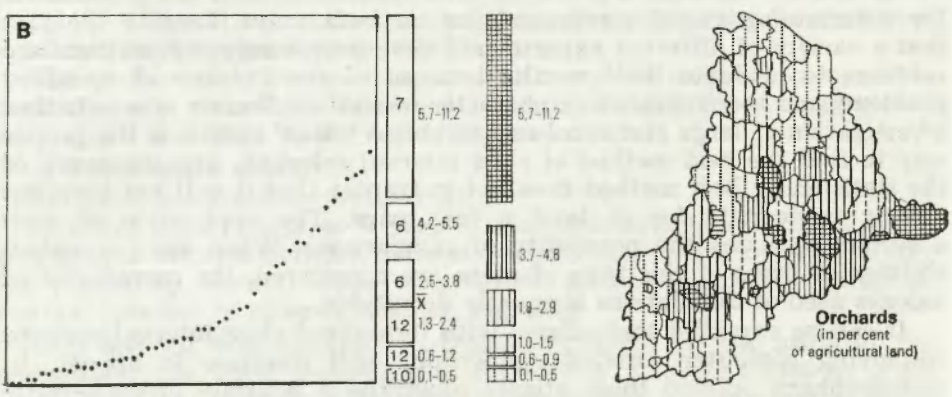


Fig. 3B

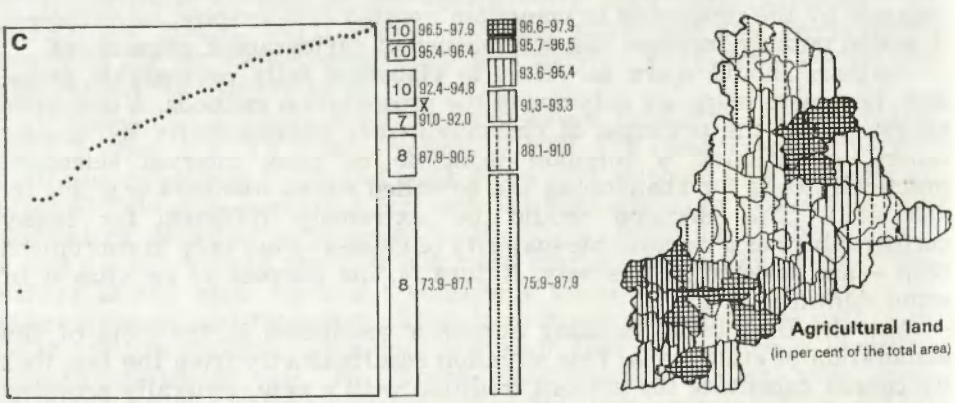


Fig. 3C

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whether the research carried out so far has been in the right direction and the very definition of the procedure of map comparison in terms of perception and statistics requires more research. It is cartographers who must take up this challenge.

* * *

Three choropleth maps of Płock voivodship, which consists of 53 administrative units are enclosed (Fig. 3). Graphic arrays for 3 subjects and the legend for 2 methods of class interval selection are included.

The first legend is composed of intervals selected with a method which seems to have been accepted by cartographers. The arithmetic weighted mean ($\bar{x}$) was computed, next both parts of the set were divided into classes of identical frequency (frequency was given in every rectangle).

The other method (pattern-filled legend) consists in class limits selection only on the basis of frequency. In principle, they are 9 element classes ($6 \times 9 = 54$), though because of value distribution this is not a hard and fast rule, the more so as there are 53 units on the map. This method of selection, very simple as it is, seems to be the most adequate for the comparison of choropleth maps. With relation to the earlier discussion: one constant is preserved here i.e. class frequency. What varies is class range. The user's attention can be easily directed to the range by means of elaborating a proper map legend. They are rectangles placed vertically, as in the cartographic convention the vertical direction stands for the third dimension 'z' in relation to the map surface. The whole legend symbolizes data range and individual rectangles, class range. As it follows from a comparison of graphic array with the legend, the application of the quantile method explicitly indicates statistical distribution. The enclosed choropleth maps illustrate three situations:

a) Data correspond to normal distribution, so an identical division into classes is obtained in both cases (Fig. 3A).

b) Graphic array clearly shows the purpose of using increasing range intervals and this division is obtained with the use of the quantile method (Fig. 3B).

c) The last map is a rare case of statistical distribution clearly suggesting decreasing intervals. The introduction of the mean value ($\bar{x}$) as the limit of the third and the fourth class markedly disturbed the sequence (Fig. 3C).

The problem of choropleth map comparison requires close study, not only in the aspect of psycho-physical research (so much in fashion among cartographers nowadays) but in the first place with the participation of geographers, who are, after all, interested in the content of regional and national atlases.

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# REGULAR DENSITY NETWORK AND ITS APPLICATION IN GEOGRAPHIC STUDIES

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A look at cartography as a branch of science will reveal internal disparities in its development. Map making methodology is one of the better developed branches of cartography. This is to be attributed to the generally acknowledged role of the map as a form of recording phenomena of a spatial character. Now that the branches of science which use the products of cartography are developing rapidly, this function can hardly meet the demand for broadly conceived cartographic information about the reality. While providing a direct record of occurrence of phenomena, the map is expected to present the content in such a way which would make possible its interpretation. That is why a search is under way for new methods of cartographic presentation which would provide for not only the recording of factual materials, but also the investigation of geographical phenomena. One of the results of this search is the new cartographic method offered in the present paper — regular density network.

The methodological assumptions underlying regular density network are responsible for the fact that this approach to the presentation of phenomena is different than in other cartographic methods. That is because regular density network reverses the relationships between the parameters of those phenomena. In this case it is not the changing values of phenomena, but the size of reference areas (mesh) resulting from the distribution of those values that constitutes the informative element. The shapes of reference areas are largely uniform, which ensures a good perception of regular density network and easy and precisely measurable comparability of different phenomena presented by means of this method.

Regular density network is made by way of transforming the content of maps made with the use of 'traditional' cartographic methods. Dot maps are particularly useful for this purpose. The first stage of making the network is to *determine the basic mesh*. This mesh is a square, as this geometrical figure is easily aggregated and disaggregated, which is of great importance in the construction of the network. The square should be so big as to cover the area of a phenomenon. In the case of the dot map it is the biggest square containing one dot. Subsequently the whole map, starting from a chosen initial point, is covered with such squares. This constitutes the basis for further stages in the construction of regular density network (Fig. 1).

In order to present the distribution of a phenomenon with the use of regular density network, one must divide basic meshes into unit meshes assuming that one dot will be contained in each of them. The division

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should be done at geometrical progression with common quotient 2 so that each dot corresponds to a possibly largest unit mesh (Fig. 2). Should a basic mesh contain one dot only, it is simultaneously a unit mesh and does not undergo division. The sizes and shapes of unit meshes depend on the number of dots and their location in the basic mesh. They can be the following geometrical figures: squares, rectangles and rectangular polygons (Fig. 2).

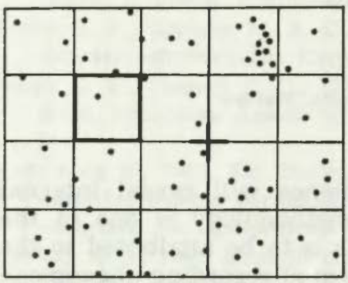

Fig. 1

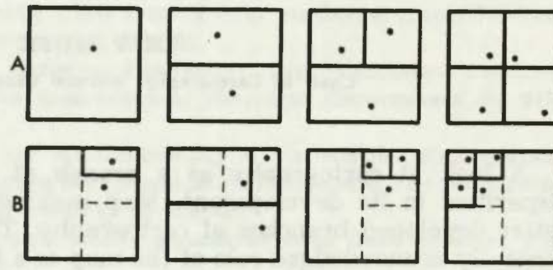


Fig. 2

Regular density network constructed according to those rules is illustrated in Fig. 3B. It was constructed on the basis of a map of rural population distribution in Suwalki voivodship (Fig. 3A).[1]

Regular density network is easily generalized. In order to perform the generalization one must first make up larger basic meshes, square-shaped and composed of four or sixteen basic meshes of the initial network. Within the newly constructed basic meshes unit meshes of the initial network are grouped in equal-number sets. The method of constructing unit meshes of the generalized network is illustrated in Fig. 4.

Knowing the methodological assumptions underlying regular density network, one can characterize it and determine its relation to other cartographic methods. The greatest peculiarity of this method is the earlier mentioned principle that the intensity of a phenomenon is presented not by referring its changing value to area, but by reversing this relationship and referring area to constant value of the phenomenon. Regular density network may be called a reversed choropleth map.

An unquestioned merit of regular density network is the fact that it combines the features of both discrete and indiscrete cartographic methods,[2] owing to which the characteristics of the phenomenon is more extensive than usually. The first feature (discreteness) makes it possible to read the intensity of a phenomenon at every point of the network. Values of this intensity are equal within an individual field and change together with the changing size of units changes, which takes place at

[1] Areas of towns and lakes were excluded from presentation with the use of regular density network.

Construction principles were described in detail in the following papers: Ratajski L., Siwek J., Regular Density Network. *International Yearbook of Cartography*, 17, 1977, 138–154; Ratajski L., Siwek J., Sieć zmiennogęsta regularna (Regular density network), *Polski Przegląd Kartograficzny*, 10, 1978, 1, 27–35.

[2] The feature of discreteness should be understood in the sense of handling area.

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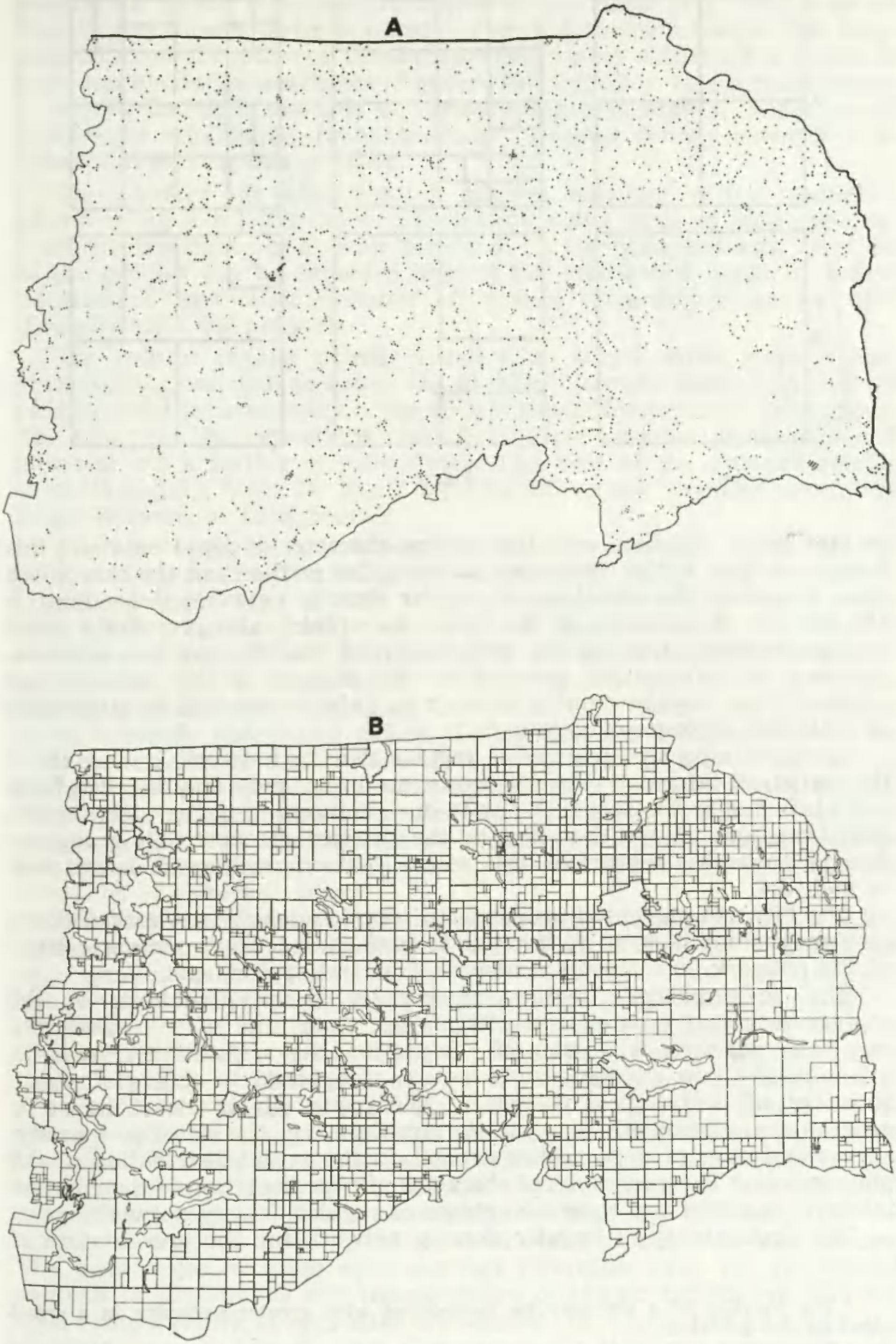


Fig. 3

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A

B

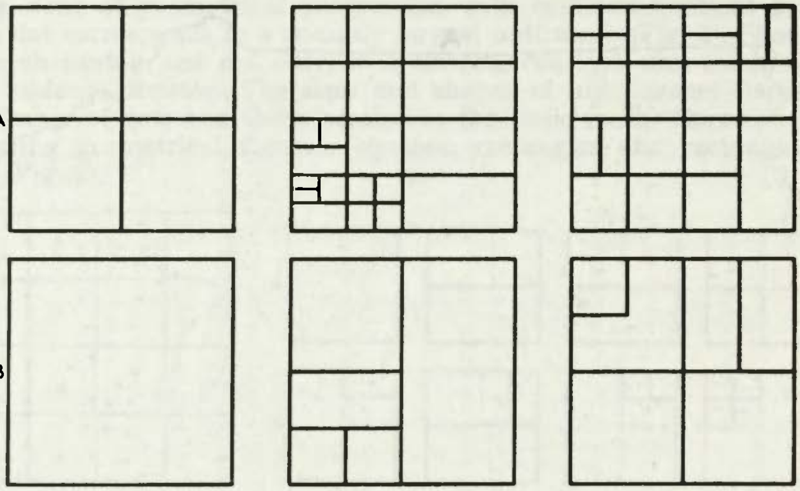

Fig. 4

an step scale. Together with the surface character of representation, this feature testifies to the connection between this method and the choropleth map. However, the structure of regular density network, dependent on the location of elements on the initial map (dots), also provides a great deal of information about the distribution of the phenomenon, with the accuracy of information growing as the meshes of the network get smaller.[3] Thus, regular density network may also be ascribed an attribution of indiscrete cartographic methods.

Another important feature of regular density network is that all of the statistical information contained in the initial map may be read from it. This is due to the fact that one-to-one relationship is the basis for the transformation of the dot map in the process of constructing regular density network. In practice, this means that one unit mesh is assigned to each dot.

The hitherto presented properties of regular density network concern cartographic methods only. In order to perform a versatile characteristics of the network, one must consider its practical applications.

The fundamental function of regular density network is the *representation of geographical phenomena.* As a kind of the choropleth map, the network is a way of illustrating the spatial differences in intensity of those phenomena. However, as opposed to choropleth map, it is not of a statistical character. The name which fits it better is geographical choropleth map, as its structure, i.e. the density, sparsity, shapes and sizes of unit meshes depend on the actual distribution of the phenomenon.[4] The geographical character of representation of distribution intensity is one of the basic advantages of regular density network.

The applicability of regular density network for the presentation of

[3] The location of a dot may be reproduced with greater accuracy in a small mesh on the initial map.

[4] The shapes are adjusted to some extent only, within the limitations imposed by the assumptions of the method.

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phenomena is not restrained to monothematic maps (Fig. 3B). It seems that it may find broader applications on polythematic maps. The large accumulation of content on those maps often makes it difficult to elaborate such graphic design which would ensure full legibility. It is then necessary to search for such methods of cartographic presentation which would provide for maximum 'graphic economy'. Regular density network is an attempt at solving this problem.

The number one advantage of 'graphic economy' is the possibility of conveying a relative lot of information using little of map capacity. With the application of a wider variety of cartographic methods, the slope of the content can be extended beyond the established limits. It should be stressed that other methods of surface presentation can be used paralelly with the network.

The role of regular density network on polythematic maps is that of presenting background issues, the so-called thematic background, which facilitates the interpretation of the distribution of fundamental phenomena. The fact that the network is used for the presentation of 'background' issues is not a matter of coincidence. This role of the network results from its graphic form. Its linear form facilitates the intended perception of the network as background.

Another application of regular density network, secondary to presentation, is the *recording of geographical data.* The method of presenting those data in map form, considered from the viewpoint of their further utilization in research or practical activity, is often inconvenient for the user. Methodological and editorial aspects excepted, it is due to a lack of uniformity among the criteria of data reference. The data are recorded basing on area units of different size and shape or on unevenly distributed points, the location not being a consequence of the character of distribution of the phenomenon. Moreover, various kinds of data are assigned to variously located points, which additionally compounds comparative studies. In view of that, it seems evident that an arrangement of data through at least a partial uniformization of the principles of reference would result in a simplification and greater efficiency of empirical works.

Efforts are made in geographical works to divide territories into equal or nearly area units, which are the basis for the collection or adjustment (arrangement) of data subsequently used in research. Generally speaking, two kinds of such territorial division can be distinguished. The first — irregular division is closely connected with the administrative division (very seldom with the physiographic division). Its advantage is undoubtedly the availability of statistical data, which are most often collected and processed in reference to the administrative division. However, this is also a reason for a significant limitation on the usefulness of this kind of division. It becomes next to useless at the moment when administrative changes are introduced, as the old and the new areas of data reference cannot be compared. This shortcoming is effectively eliminated in the territorial division made up of areas of standardized sizes and shapes. The advantages of using such abstract reference units for the spatial analysis of phenomena are: independence of the administrative division, total comparability of area sizes and chapes, the facility of grouping and dividing them, and in the case of square units, the arrangement in rows and columns. This last feature facilitates the determination of the location



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of each field in the system of rectangular co-ordinates and, consequently, the notation of the location of individual elements of the phenomenon.

Regular density network may be treated as a set of area units with the above described properties. Those properties are inherent in the basic meshes of the network, which, being squares, satisfy the condition of standardized sizes and shapes. The squares on which the network is constructed are at the same time to be used as fields for the recording of geographical data. However, recording proper is performed with the use of individual meshes, which are the smallest record areas. Any changes in the structure of a phenomenon are tantamount to changes in their structure. When the intensity of a phenomenon grows with time, individual fields have to be divided into smaller fields, and when the intensity decreases, they are aggregated to form larger area units. A comparison of the superimposed fields of an up-to-date and an outdated network makes it possible to observe the current changes in the intensity of phenomena and their trends, i.e. the dynamic progress of processes.[5]

The above described are by no means all the possible uses of regular density network. It seems that regular density network has another significant role to play in *the study of spatial relationships which occur between geographical phenomena*. Naturally, maps are the most important instrument in this study. However, the use of maps, which present the space of geographical phenomena in a traditional manner, involves certain obstacles resulting mainly from the limited possibilities of comparing their content, which is represented with the use of different cartographic methods. In order to make comparisons between cartographic images of different phenomena possible, they must be transformed so that a common denominator is obtained, which ensures comparability. In the case of comparative studies with the application of mathematic-statistical methods, this role is played by such parameters as the arithmetic mean and the square mean deviation. In the case of cartographic methods, regular density network seems to be the best method of transformation. The role of common denominator is in this case performed by the area of individual fields, which are perfectly comparable elements. The steps aimed at determining the relationship occurring between geographical phenomena, i.e. correlations, consist in comparing the sizes of respective individual fields and interpreting the findings.

Research procedure aimed at determining correlations between phenomena on the basis of regular density network will be described on an example of the distribution of rural population (Fig. 3A) and the distribution of surfaced roads (Fig. 5A) in Suwalki voivodship. In order to obtain comparable pictures of those phenomena, the construction of the two networks (Fig. 3B and 5B) was based on equal-size basic meshes. As the initial networks were overly detailed, they were generalized, i.e. unit meshes were grouped in sets of four (Fig. 6A and 6B). As the values of dots on initial maps were, respectively, 100 people and 1.4 km, the values of meshes in generalized networks grew to 400 people and 5.6 km. Subsequently the networks, plotted on transparent material, were superimposed to obtain diverse configurations of unit meshes. The meshes of the two networks can be ordered according to size and simultaneously

[5] When examining the dynamics of phenomena, the procedure is the same as for the examination of correlations, which will be described later in the paper.

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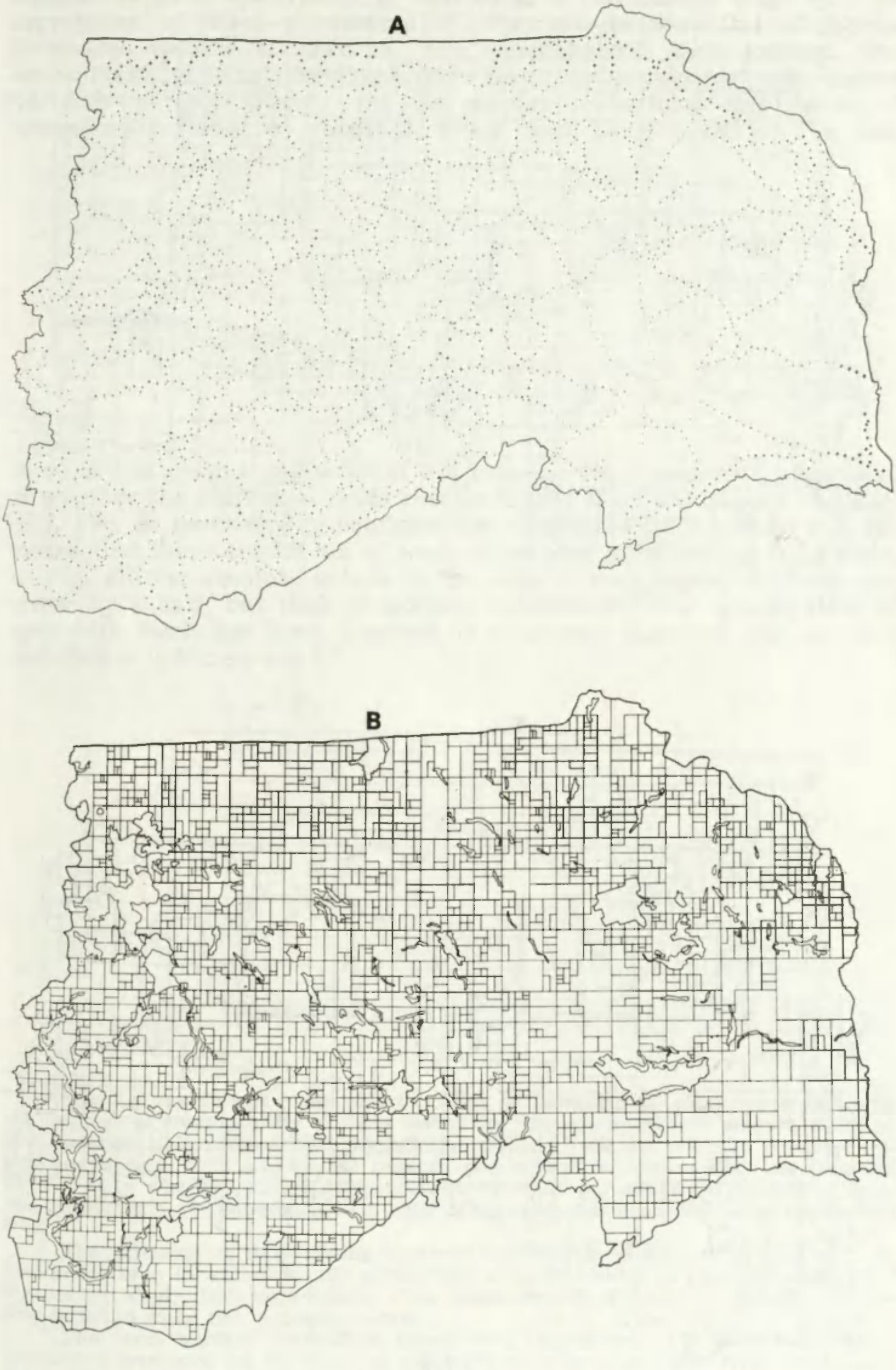


Fig. 5

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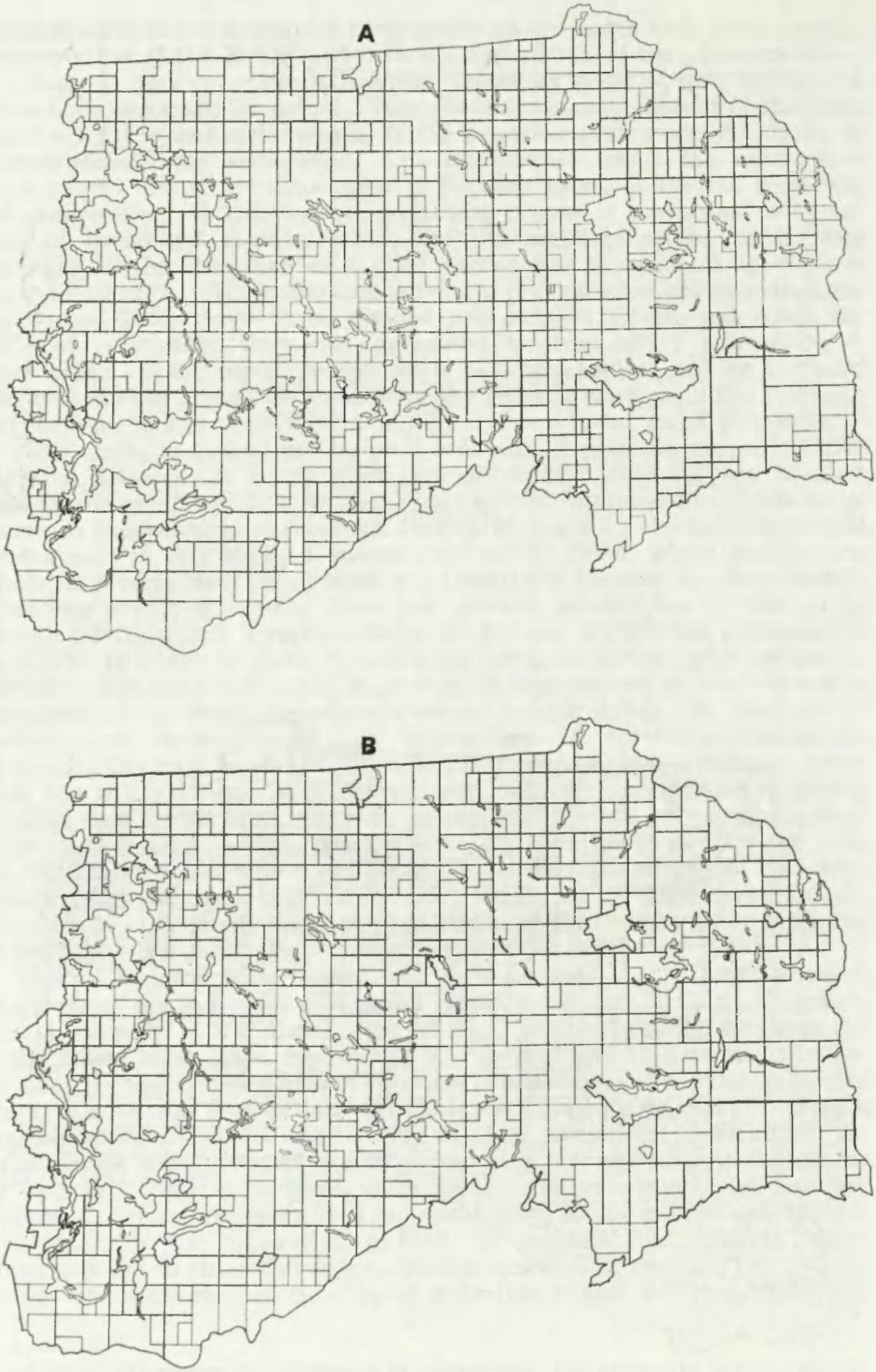


Fig. 6

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assigned appropriate values of intensity of phenomena (Fig. 7).[6] The correlation of those phenomena is expressed in the ratio of figures (intensity values) assigned to the superimposed unit meshes. The denominator of such a fraction always features the values of independent variable '$a$' (population), and the numerator features the values of dependent variable '$b$' (roads). If $a = b$ then $b/a = 1$, and in this case

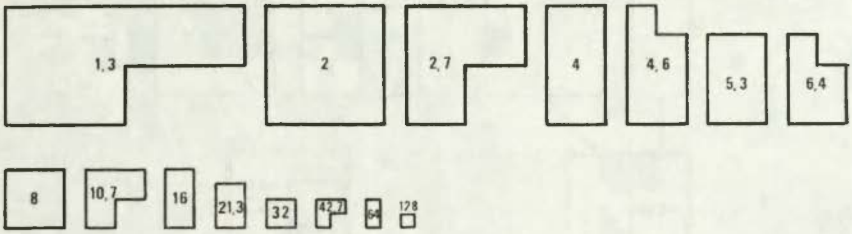


Fig. 7

there is full correlation between the investigated phenomena, regardless of whether the individual fields overlap totally (Fig. 8A) or only partially (Fig. 8B). In practice, the configuration of meshes presented in Fig. 8A means that there are 5.6 km of roads in an area inhabited by 400 people. In Fig. 8B the absolute values in the area of overlapping of fields are lower by a half, but their proportion is identical. Such a saturation of area with roads has been accepted as optimum,[7] therefore the so-called correlation index equals 1.[8]

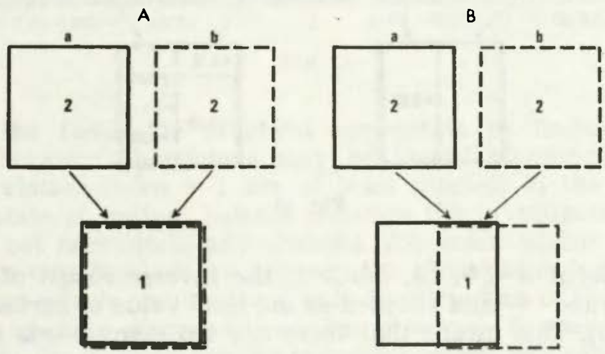


Fig. 8

[6] The figures do not mean actual values of intensity of phenomena, but only the degrees of changeability of those intensities, therefore they are easy to compare. For instance, if in some arbitrarily selected fields of the network the recorded population density was 2.3, 4.6, 9.2 persons per square kilometre and the recorded road density was 0.03, 0.06, 0.12 kilometres of roads per square kilometre of area, the proportions of changeability in both cases could be expressed with the figures 2:4:8.

[7] The criterion of determining optimum saturation of area with highroads as 5.6 km for area inhabited by 400 people was adopted exclusively for the purpose of the present study. It is appropriate when mean density of roads in Suwalki voivodship is taken to be the optimum value.

[8] The term 'surface correlation index' was introduced to indicate correlation coefficient computed on the basis of regular density network. The term emphasizes the surface reference of the input data and the results of the study.

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If $a > b$ then $b/a < 1$, which means that the length of roads in the given area is insufficient in relation to population. Hence the index of surface correlation has a negative (−) value (Fig. 9).

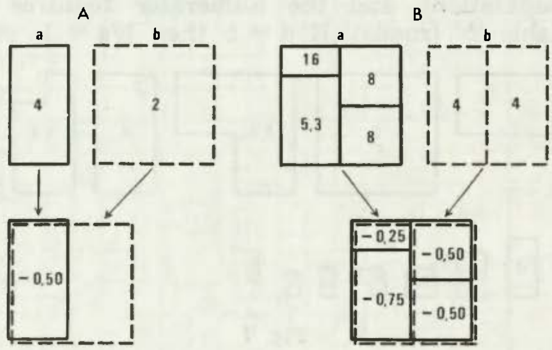


Fig. 9

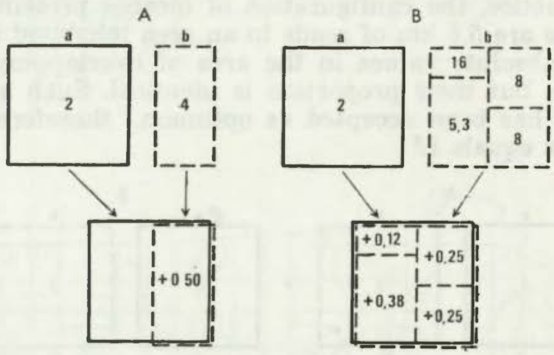


Fig. 10

In the case of $a < b$, i.e. $b/a > 1$, the inverse result of the division should be marked '+' and adopted as the final value of surface correlation index (Fig. 10). This means that there are too many roads in relation to population.

On the basis of the above described assumptions a map of correlation of the distribution of rural population and surfaced roads in Suwałki voivodship was prepared (Fig. 11).

In comparison with the generally applied measures of correlation, surface correlation index determined with the use of regular density network is the closest to the concept of correlation coefficient, as the two convey the strength of correlation between spatial phenomena in the same form. However, unlike correlation coefficient, whose spatial reference, connected with (for instance) regularly distributed control points, is not a result of the actual distribution of phenomena, surface correlation index characterizes exclusively uniform areas, the sizes of which are exponents of changes of the index. This enhances its geographical character.

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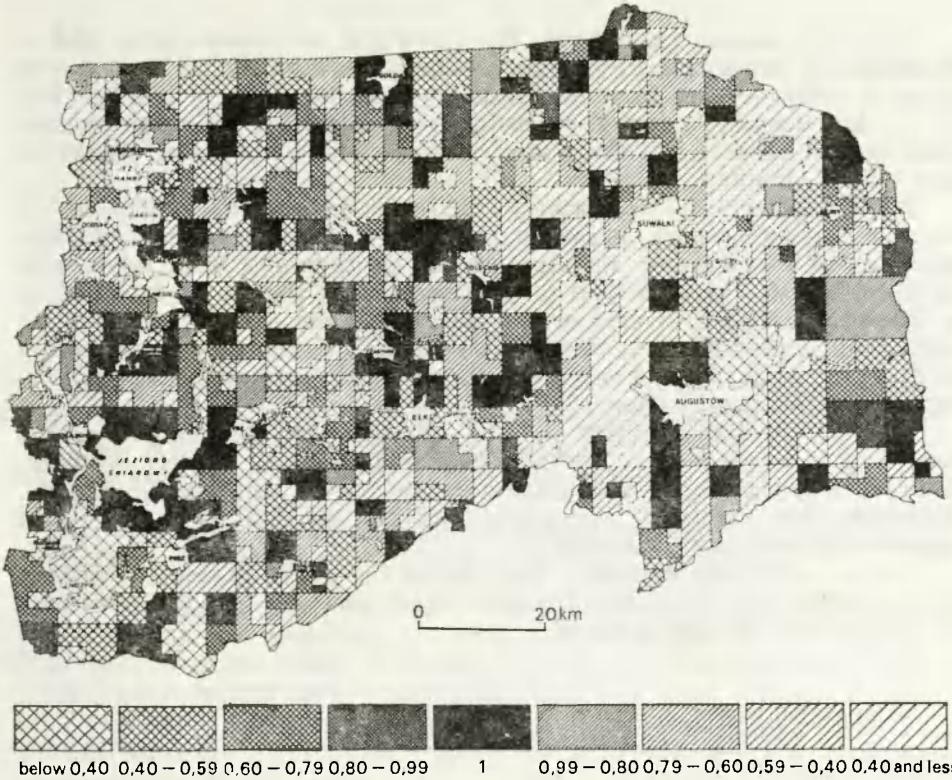


Fig. 11

One of the fields for practical application of findings concerning correlation between phenomena may be *spatial planning*. The areas of surface correlation index = 1 are of least interest to the planner. This indicates a state of mutual balance between the investigated phenomena, which does not necessitate any changes. An index whose value is other than 1 means that the balance between the phenomena is disrupted. This indicates areas which require changes in the structure of those phenomena so that the existing disproportions are removed. A map of correlation together with the regular density networks which were the bases for its elaboration provide for a computation of the absolute values of 'shortage' or 'excess' in the occurrence of phenomena (surfaced roads in this case). An application of regular density network for the planning of optimum road distribution should be deemed useful in the macro-regional scale. The limited applicability is due to the degree of generalization of the image of correlation between phenomena constructed with the use of the network, which is a consequence of the principles of network construction and the use of class intervals on the final map. Therefore the fields determined on the map, should not be considered completely invariable as regards the shape and size or the degree of correlation; they should rather be seen as a kind of zones with similar correlation and somewhat unstable borders. A determination of those zones is needed for more detailed planning decisions made on the basis of large-scale maps.

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* * *

Presented above have been the principles of construction and a discussion of issues related to regular density network. It has been shown to be a many-purpose method. Actually, it is not a single method, but *a regular density network investigation system*, which encompasses presentation, recording, a study of correlations and development dynamics and spatial planning.

Due to the specific character of the construction and application of regular density network, it cannot be assigned a single place among the branches of cartography. Its place should be regarded from two points of view. Firstly, as a method of presentation, it should be included in a theoretical branch of cartography-cartology, and within cartology, to cartographic methodology. Secondly, as it is a result of transformation of different maps and with regard to its practical applications it should be included in practical cartography.

Finally, one factor important from the practical viepoint should be noted, as it might restrict the applications of regular density network. This factor is the labour-consuming character of the construction process. However, the necessary operations can be speeded up by way of introducing automated procedures.

Owing to the experimental character of the above presented method, the solutions offered require frequent verification so that its usefulness in geographical studies is tested.

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# LIST OF CARTOGRAPHIC RESEARCH CENTRES IN POLAND ATTACHED TO GEOGRAPHIC FACULTIES AND INSTITUTES

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Uniwersytet Warszawski. Wydział Geografii i Studiów Regionalnych (Warsaw University. Faculty of Geography and Regional Studies)

**Katedra Kartografii (Chair of Cartography)**
Krakowskie Przedmieście 30, 00-927 Warszawa
Exists since November 1950
Head: Asst. prof. Dr. ing. Wiktor Grygorenko. Staff: 20 people (2 asst. professors, 7 research associates, 5 assistants, 6 technicians)

Main research orientations: General theoretical problems in cartography — mathematical modelling of the map content and form, theory of cartographic communication, methods of cartographic representation, map analysis. Atlas cartography — theoretical problems and editing of geographical atlases. School cartography — new types of school thematic maps, particularly complex and synthetic maps. Application of computers and automation to map generalization process. History of Polish cartography, particularly searching the accuracy of old maps. Interpretation of geographical environment on air photos and satellite images.

Polska Akademia Nauk. Instytut Geografii i Przestrzennego Zagospodarowania (Polish Academy of Sciences. Institute of Geography and Spatial Organization)

**Samodzielna Pracownia Kartografii (Independent Cartographic Laboratory)**
Krakowskie Przedmieście 30, 00-927 Warszawa
Exists since October 1953
Head: Dr. Michał Najgrakowski. Staff: 10 people (2 research associates, 3 assistants, 4 specialists cartographers, 1 technician)

Main research orientations: Designing, compilation and editing of the National Atlas of Poland, as well as other regional atlases. Methodological advice and coordination of cartographic work realized by other research units of the Institute. Cartographic methods used for small-scale thematic maps, particularly for environmental and agricultural maps. Cartographic documentation and cartobibliography.

## WROCŁAW

Uniwersytet Wrocławski im. Bolesława Bieruta. Wydział Nauk Przyrodniczych, Instytut Geograficzny (Bolesław Bierut Wrocław University. Faculty of Natural Sciences, Geographical Institute)

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**Zakład Kartografii (Cartographic Department)**
Plac Uniwersytecki 1, 50-137 Wrocław
Exists since October 1954
Head: Asst. prof. Dr. Władysław Pawlak. Staff: 12 people (1 asst. professor, 3 research associates, 1 assistant, 7 technicians)

Main research orientations: School cartography, particularly atlases and wall maps for primary schools. Regional complex atlases — methodological and editorial problems, designing and editing of atlases for south-western Poland. Computer assisted geomorphometry and cartometry. Cartographic reproduction, particularly with reference to relief shading. History of cartography — development of Polish tourist cartography.

## LUBLIN

Uniwersytet Marii Curie-Skłodowskiej. Wydział Biologii i Nauk o Ziemi, Instytut Nauk o Ziemi (Maria Skłodowska-Curie University. Faculty of Biology and Earth Sciences, Institute of Earth Sciences)

**Zakład Kartografii (Cartographic Department)**
Ul. Akademicka 19, 20-033 Lublin
Exists since October 1964
Curator: Asst. prof. Dr. Jan Buraczyński, Staff: 14 people (5 research associates, 1 assistant, 8 technicians)

Main research orientations: Mathematical cartography — application of computers to the construction of cartographic graticules for world maps; atlas of cartographic graticules. Methods of cartographic representation and map analysis — isopleth method and basic unit areas in the representation of statistical data. Thematic cartography — methodological problems and practical experiments concerning maps of population, settlement, and agriculture. History of mathematical and thematic cartography.

## GDAŃSK

Uniwersytet Gdański. Wydział Biologii i Nauk o Ziemi. Instytut Geografii (Gdańsk University. Faculty of Biology and Earth Sciences, Institute of Geography)

**Zakład Kartografii (Cartographic Department)**
Zamkowa Góra 11, 81-713 Sopot
Exists since October 1973
Head: Dr. Jan Szeliga. Staff: 11 people (3 research associates, 2 assistants, 6 technicians)

Main research orientations: Geomorphometry and cartometry of large and small relief forms of sea bottom. Study of dynamics of the sea shore zone on the basis of air photos. Cartographic representation of chosen population problems. History of cartography — development of land and marine cartography of the Polish Baltic coast till the end of the 18th century.

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Uniwersytet Jagielloński. Wydział Biologii i Nauk o Ziemi, Instytut Geografii (Jagiellonian University. Faculty of Biology and Earth Sciences, Institute of Geography)

**Zakład Kartografii i Teledetekcji (Department of Cartography and Remote Sensing)**

Ul. Grodzka 64, 31-044 Kraków

Exists since March 1979

Head: Dr. Kazimierz Trafas. Staff: 6 people (2 research associates, 1 assistant, 3 technicians)

Main research orientations: Application of cartographic methods to geographical regionalization. Thematic cartography, particulary mapping of natural environment. Regional atlases — methodological problems, designing, compilation and editing of complex atlases for southern Poland. Application of remote sensing to thematic mapping.

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Figure 1

**DISTRIBUTION OF RELATIVE DEPTHS ALONG THE SOUTHERN COASTS OF THE ATLANTIC AND PACIFIC OCEANS.** (ANTARCTIDE SHORE – GRAHAM LAND)

Annex to the article by M. Pelczar, Geographia Polonica 48

Computations were carried out in unit areas of 10000 km$^2$. Isopleth interval 500 m. Map scale 1:10 000 000

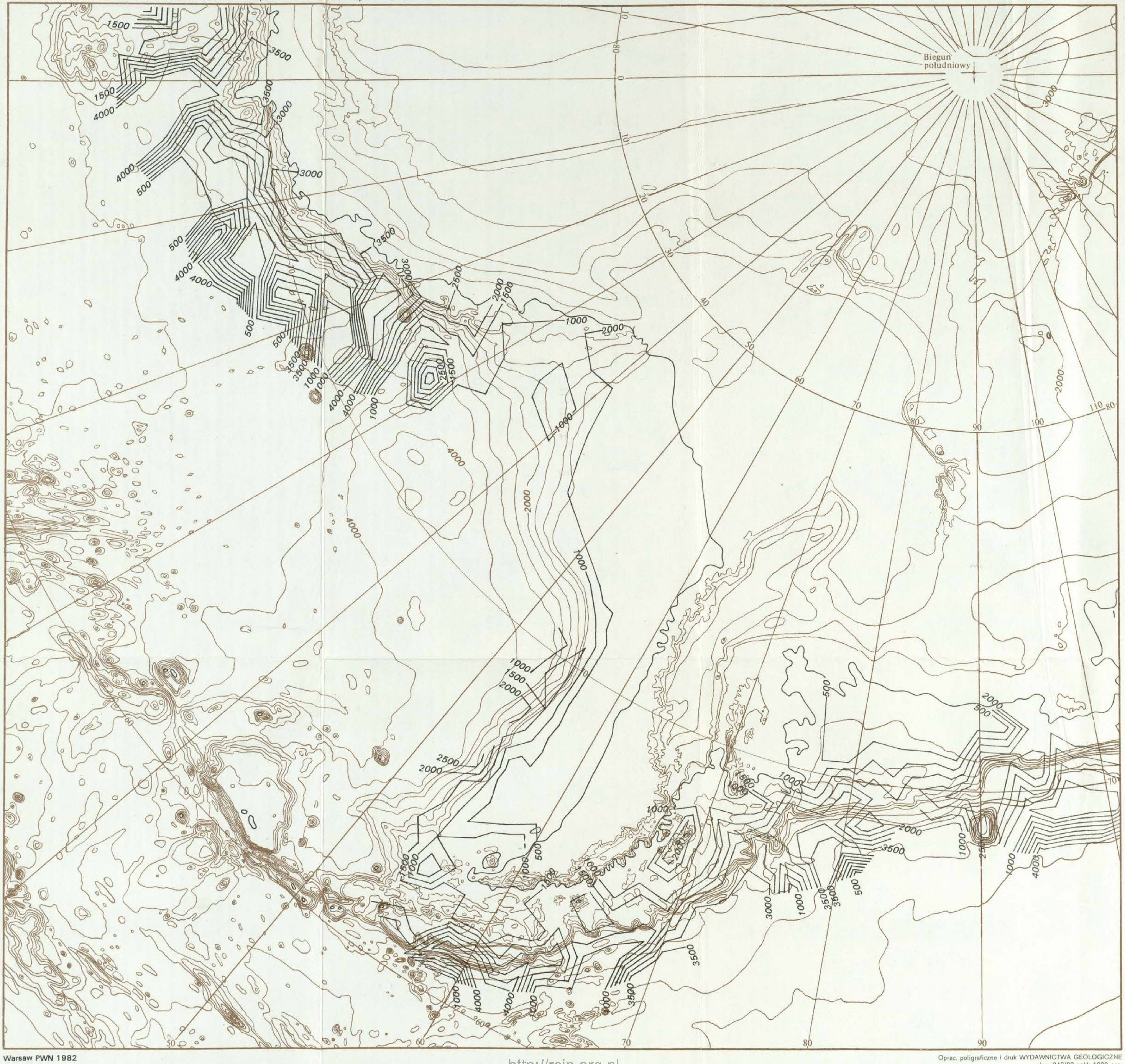


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Figure 2

**DISTRIBUTION OF RELATIVE DEPTHS ALONG THE SOUTHERN COASTS OF THE ATLANTIC AND PACIFIC OCEANS.** (ANTARCTIDE SHORE – GRAHAM LAND)

Computations were carried out in unit areas of 10000 km$^2$. Map scale 1:10 000 000

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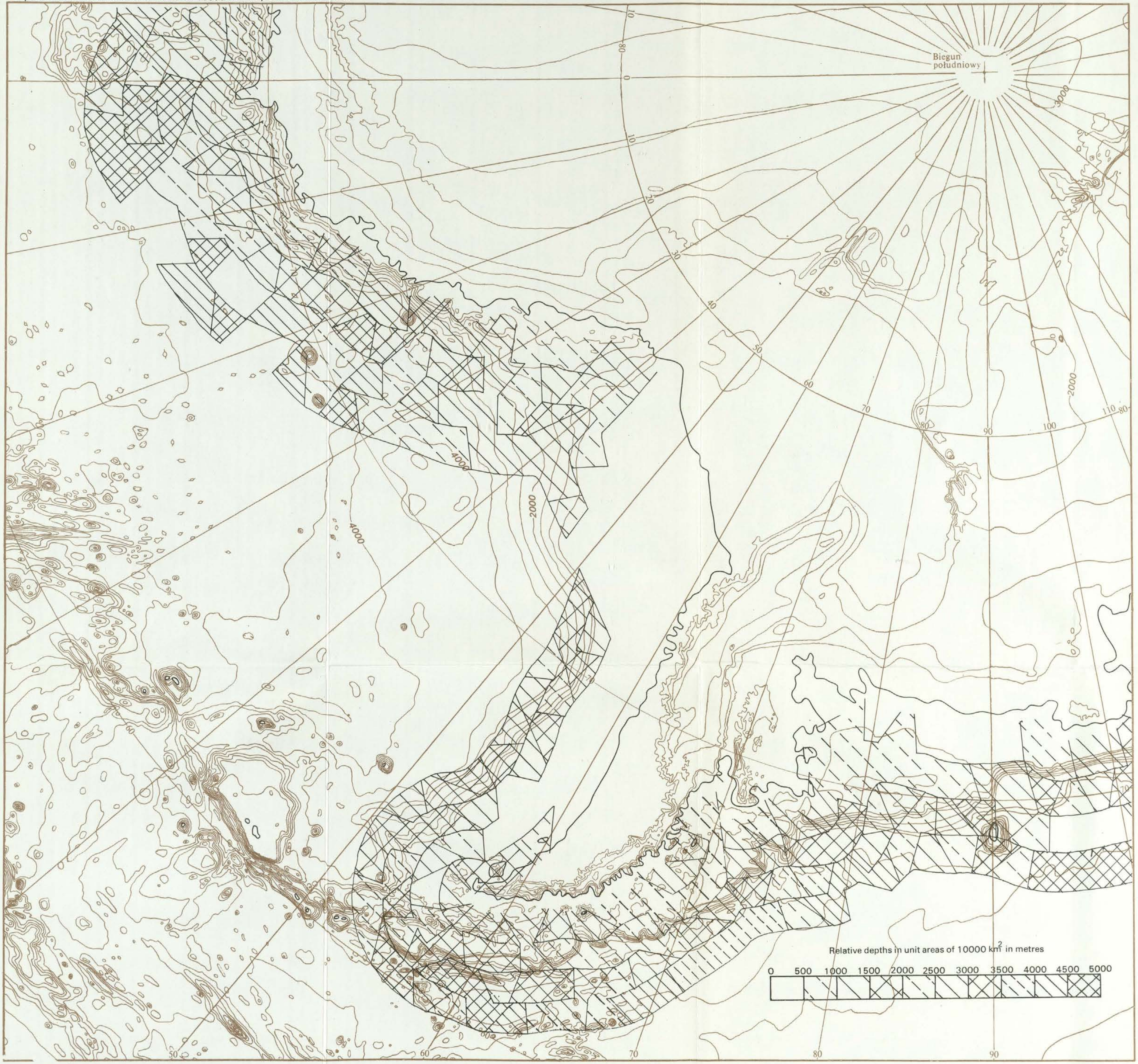


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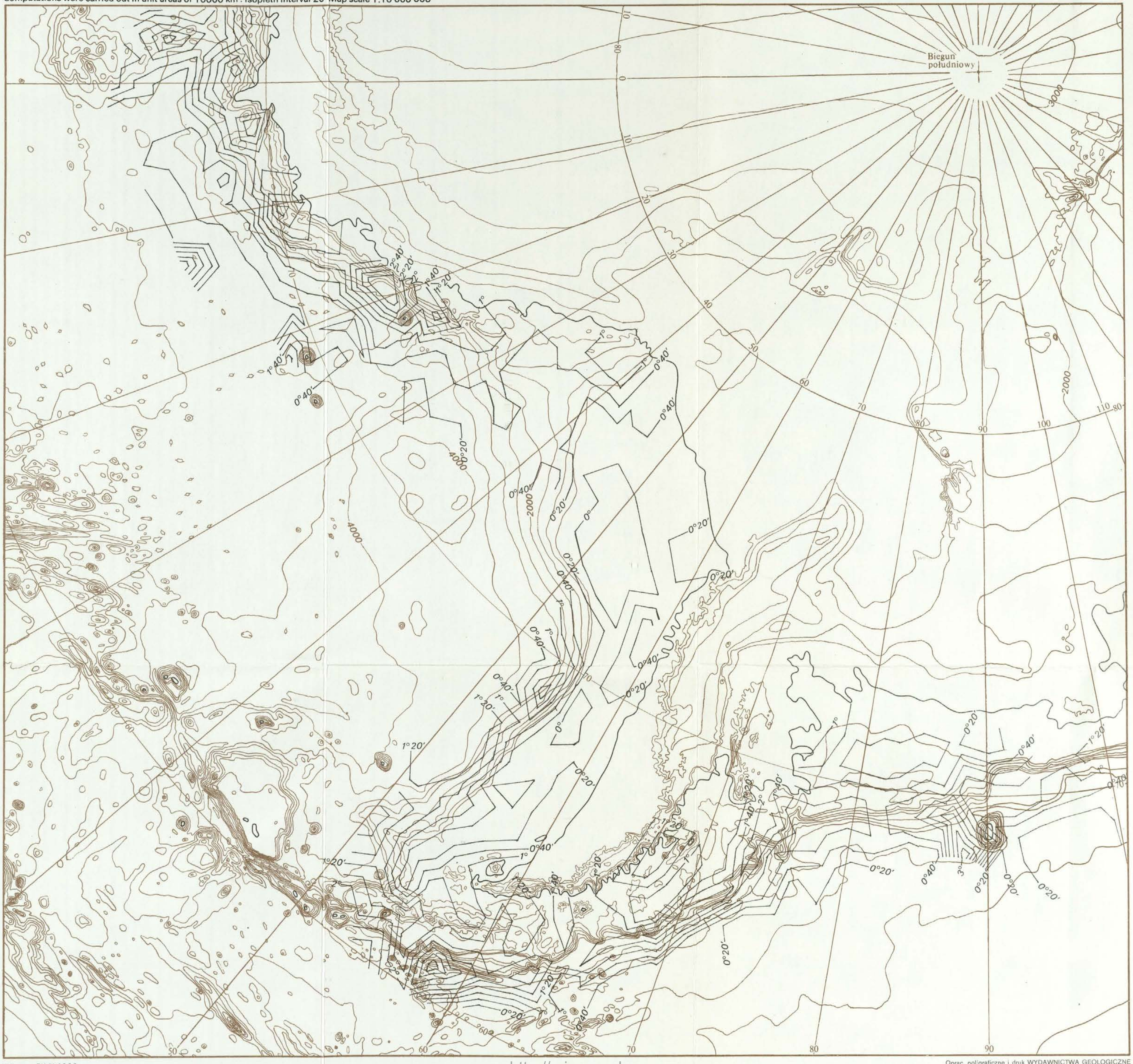
Figure 3

Annex to the article by M. Pelczar, Geographia Polonica 48

**DISTRIBUTION OF MEAN SLOPE VALUE OF COASTAL ZONE IN THE SOUTHERN PART OF THE ATLANTIC AND PACIFIC OCEANS.** (ANTARCTIDE SHORE – GRAHAM LAND)

Computations were carried out in unit areas of 10000 km$^2$ Isopleth interval 20′ Map scale 1:10 000 000

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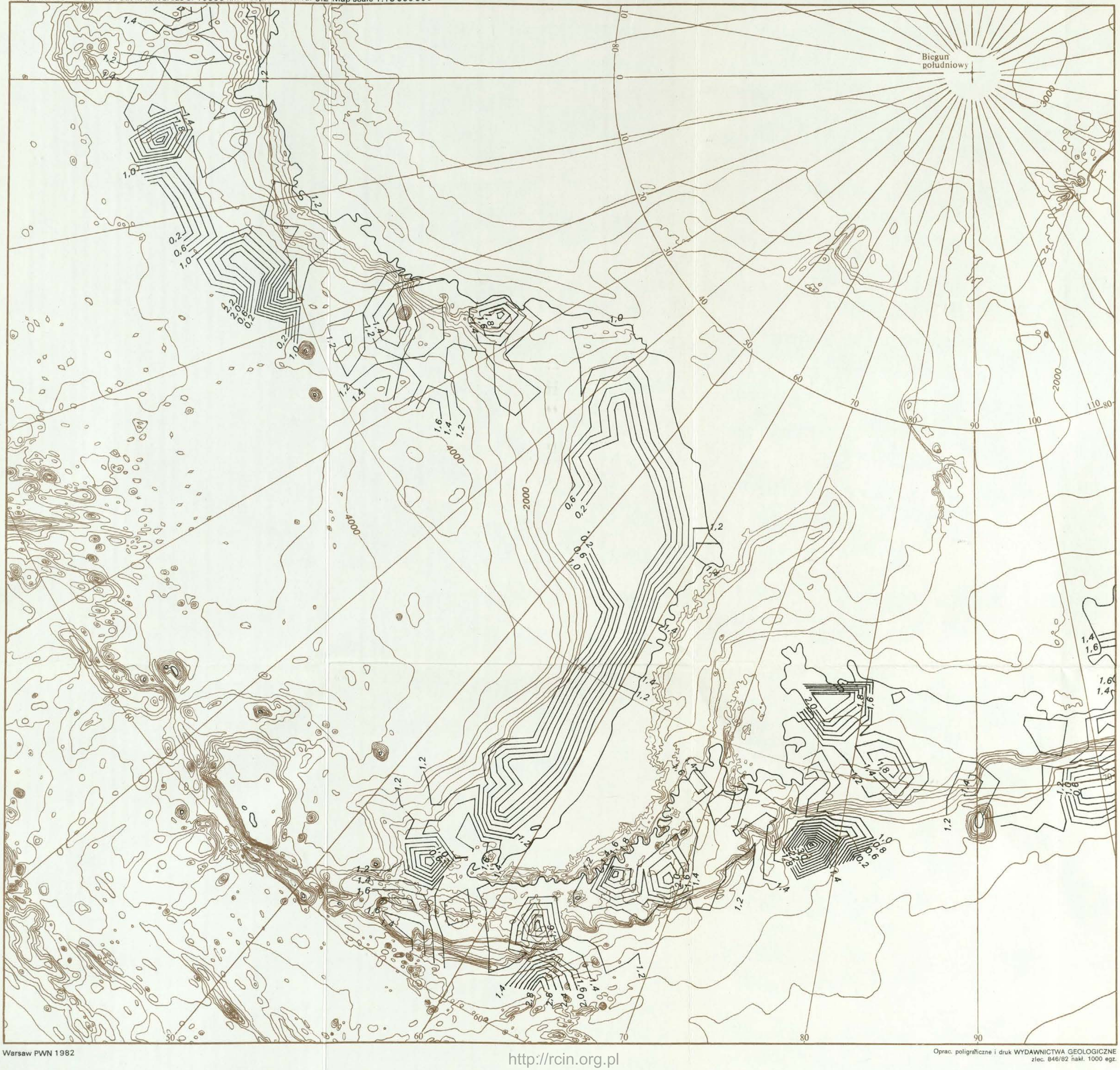
Oprac. poligraficzne i druk WYDAWNICTWA GEOLOGICZNE
zlec. 846/82 nakł. 1000 egz.

Figure 4

Annex to the article by M. Pelczar, Geographia Polonica 48

**DISTRIBUTION OF INDEX OF ISOBATH STRETCH VALUE (BOTTOM DISSECTION) OF COASTAL ZONE IN THE SOUTHERN PART OF ATLANTIC AND PACIFIC OCEANS.** **(ANTARCTIDE SHORE – GRAHAM LAND)**

Computations were carried out in unit areas of 10000 km$^2$ Isopleth interval 0.2 Map scale 1:10 000 000

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Annex to the article by S. Gurba, Geographia Polonica 48, 1982

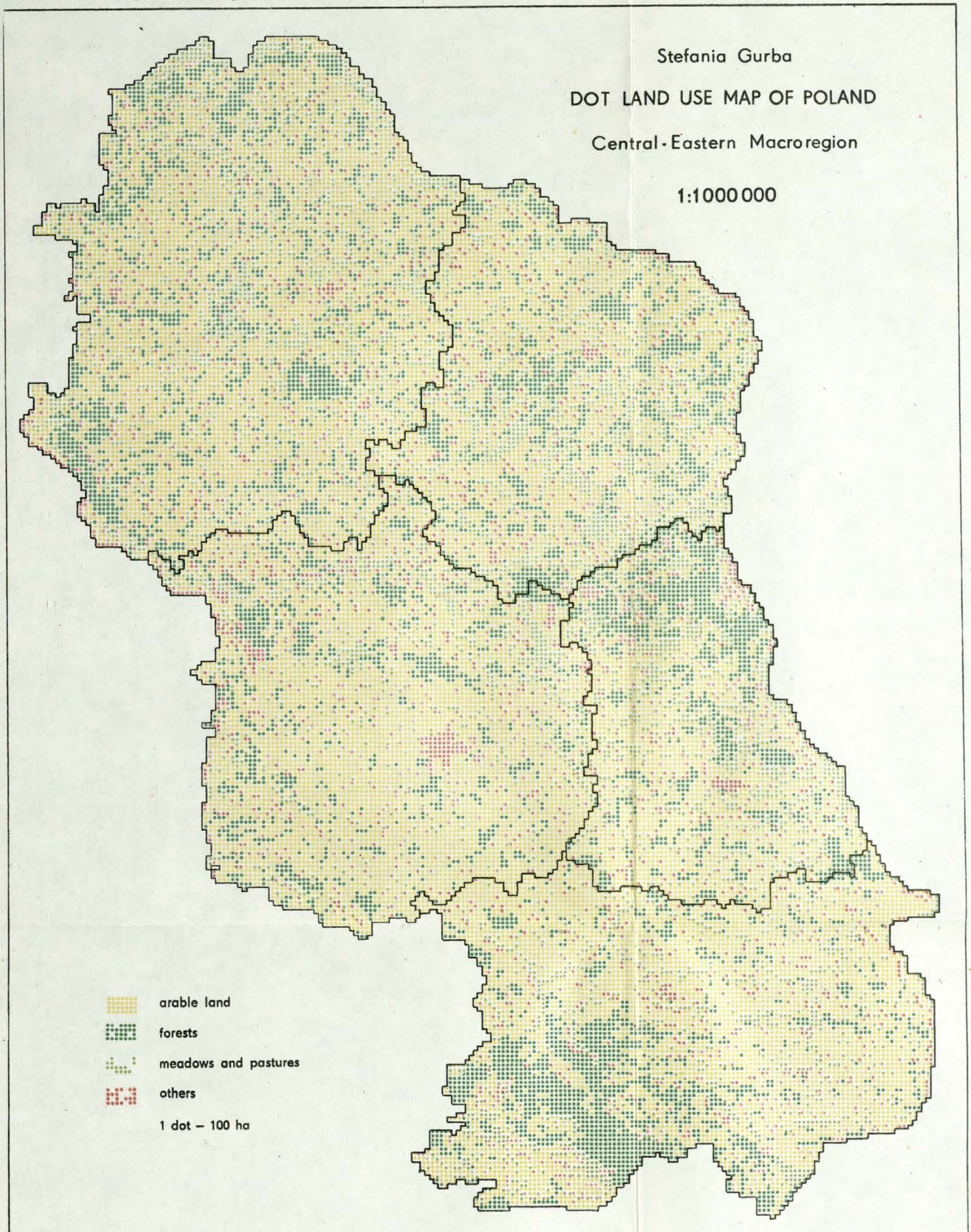


Fig. 5.

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Nr zam 2/82 Nakład 1000

Annex to the article by S. Gurba, Geographia Polonica 48, 1982

Stefania Gurba

DOT LAND USE MAP OF POLAND

Central-Eastern Macroregion

1:1000 000


Fig. 6.

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Druk Zakład Kartografii UMCS Lublin
Nr zam. 2/82 Nakład 1000

Annex to the article by S. Gurba, Geographia Polonica 48, 1982

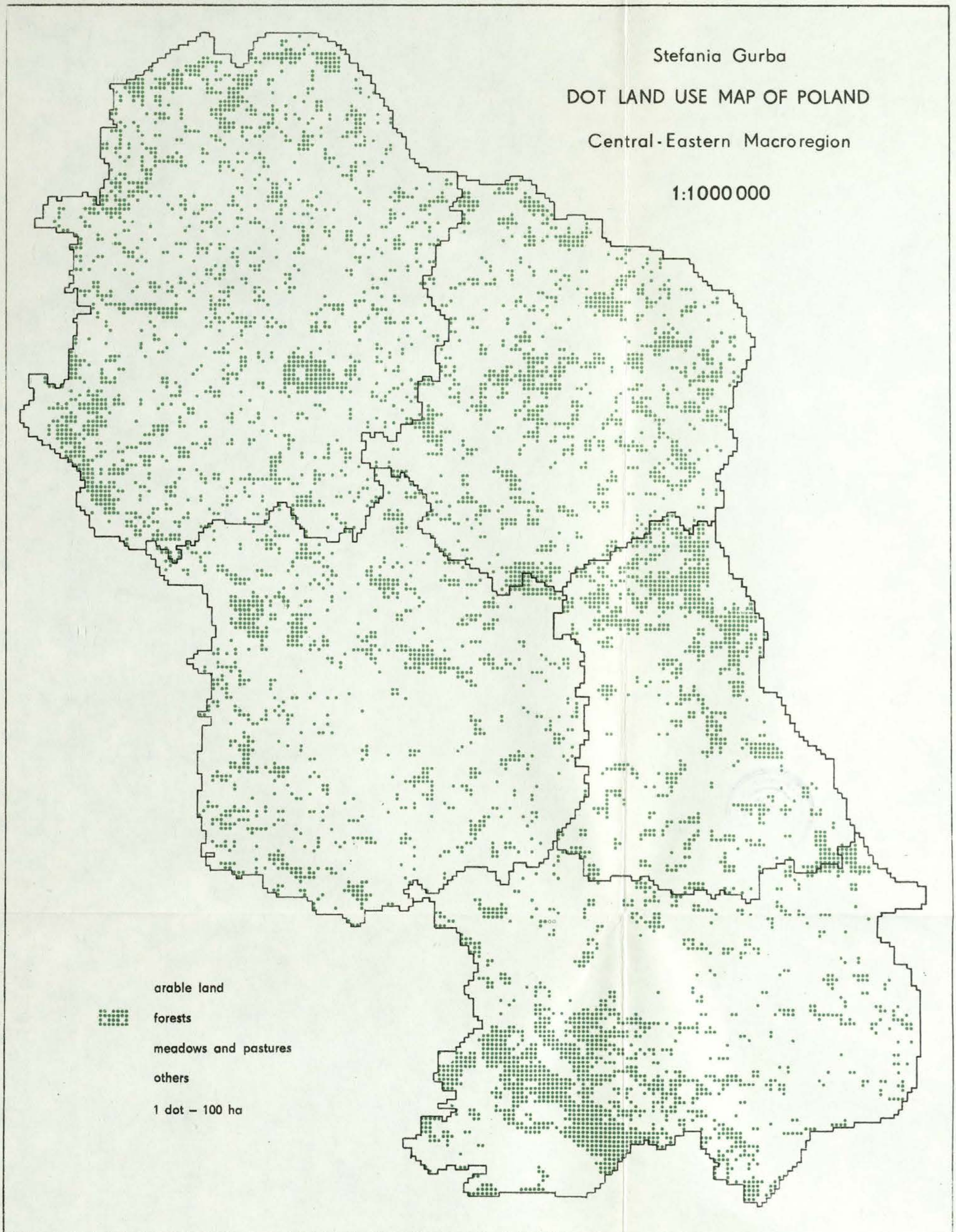


Fig. 7.

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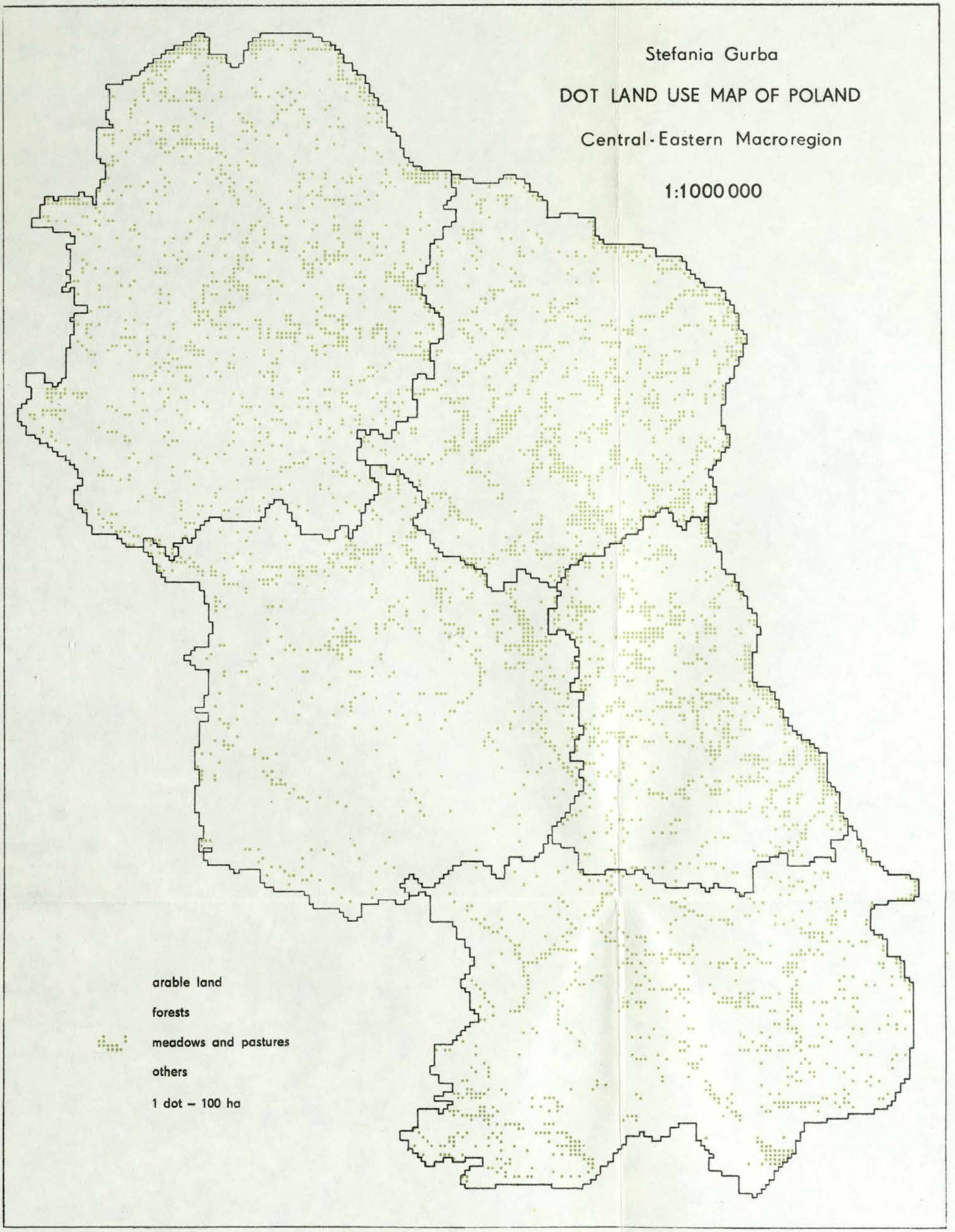


Fig. 8.

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Nr zam. 2/82 Nakład 1000

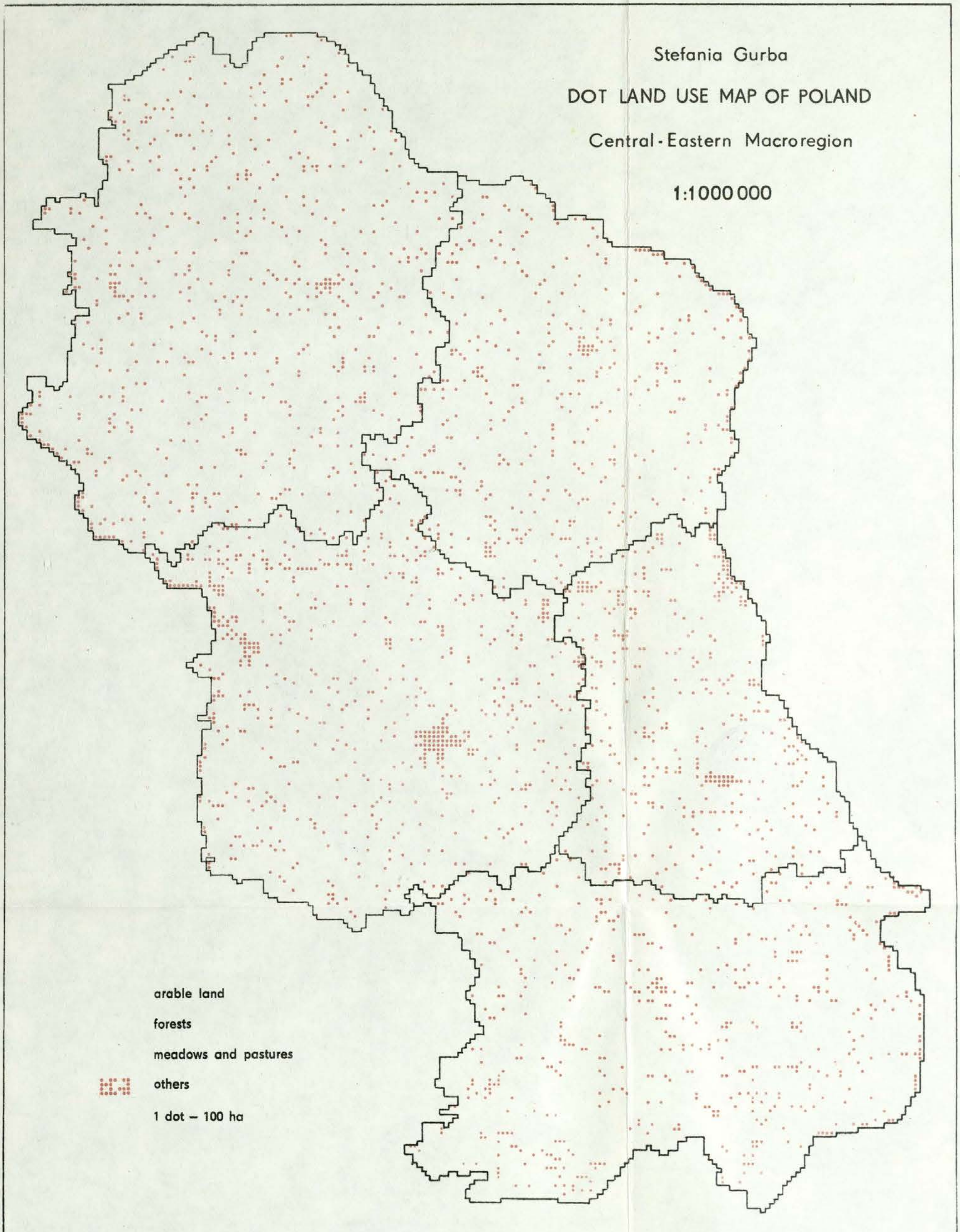


Fig. 9.

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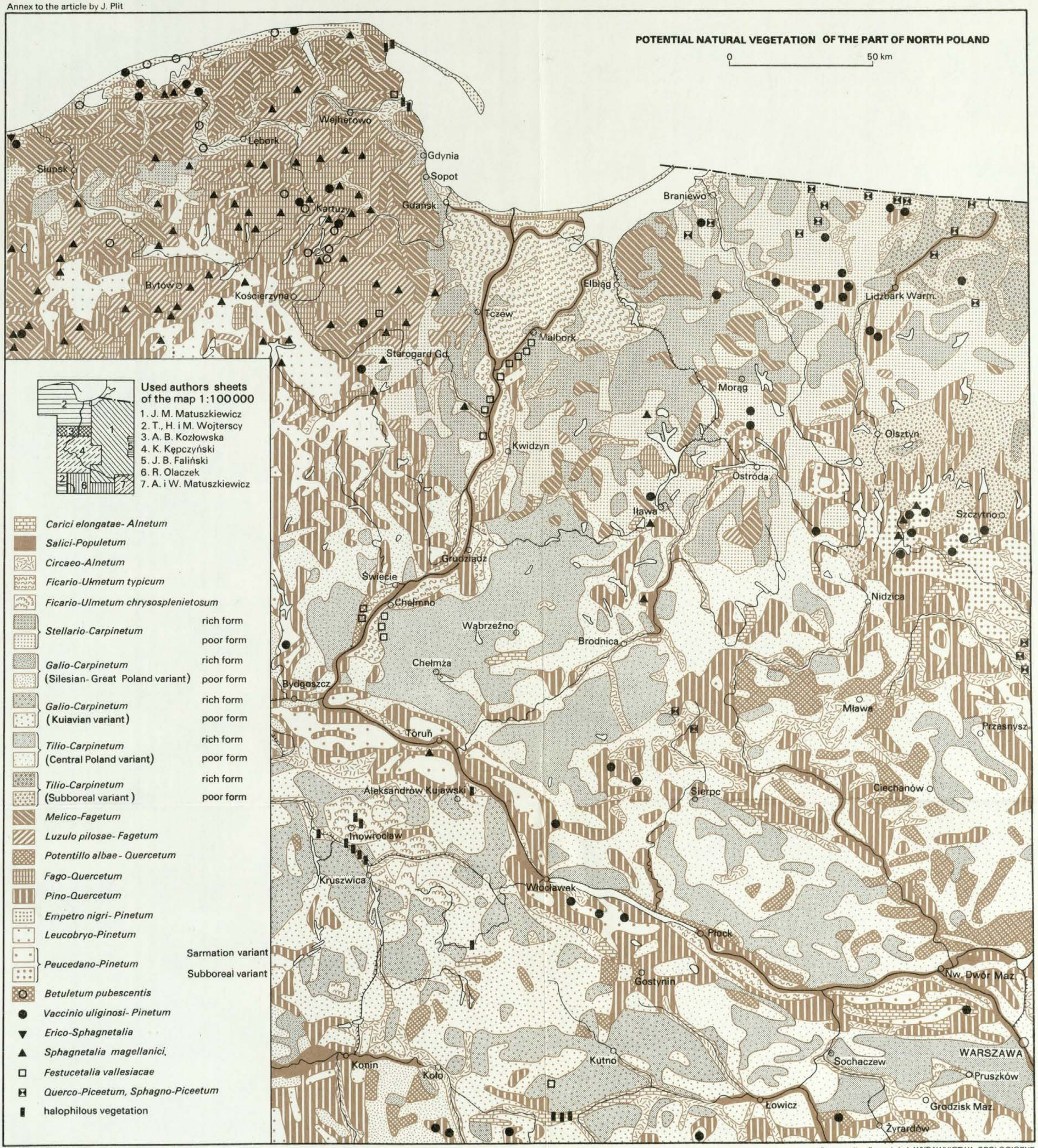
Nr zam. 2/82 Nakład 1000

Annex to the article by J. Plit

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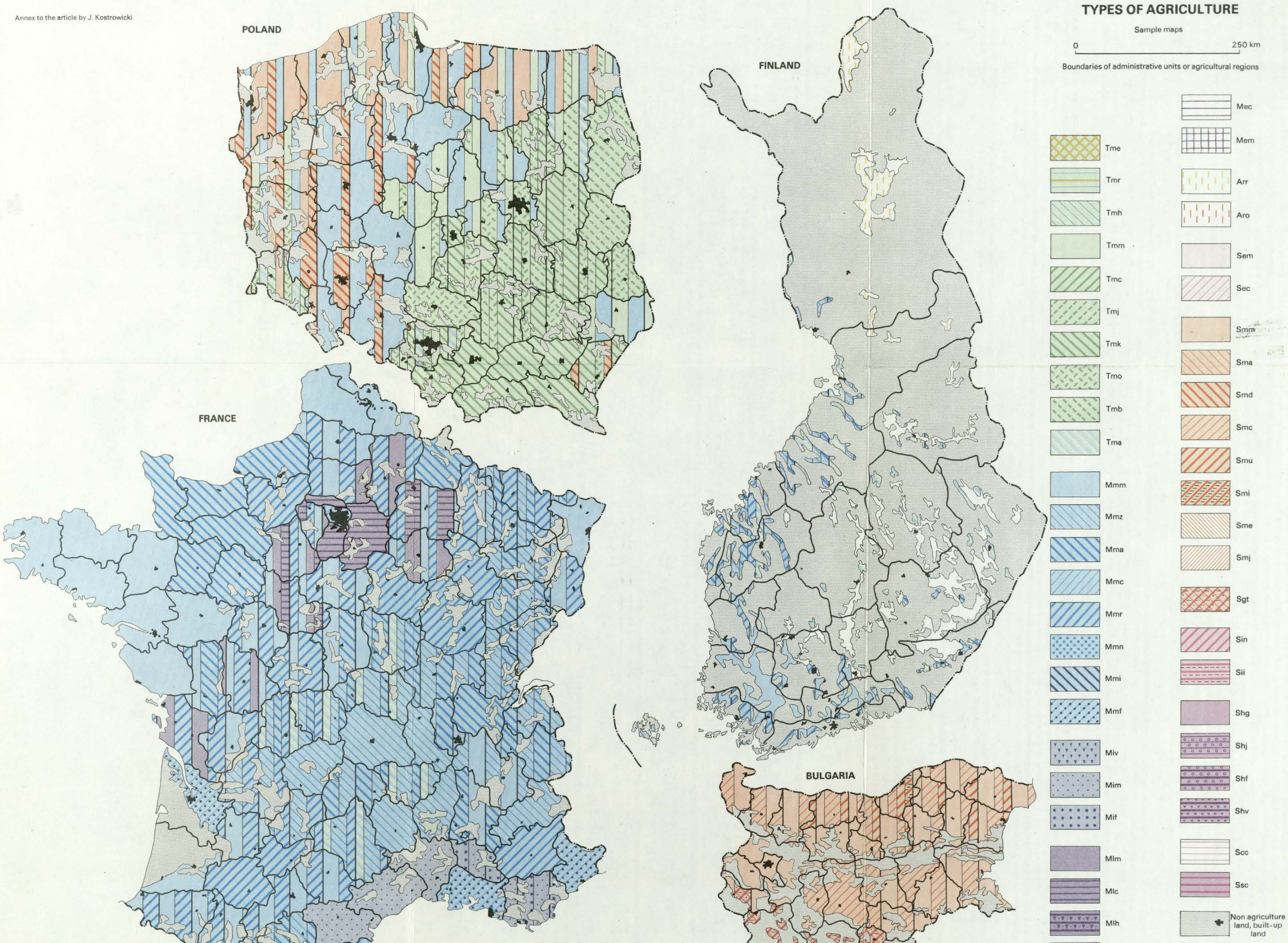
Annex to the article by J. Kostrowicki

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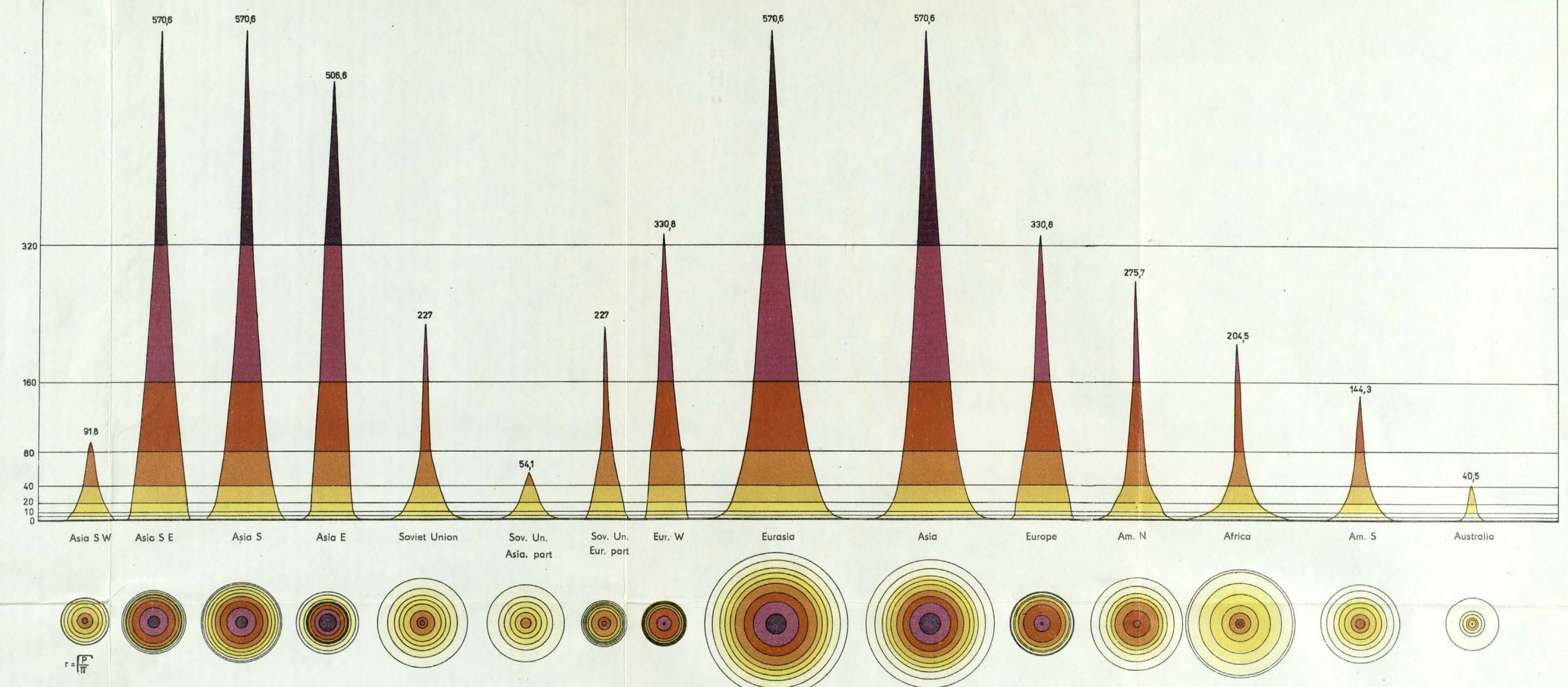
Annex to the article by F. Uhorczak, L. Grzechnik, R Zelasko Geographia Polonica 48, 1982

# DENSIGRAPHOIDS OF CONTINENTS

Fig. 4




1: 200 M

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Leszek Grzechnik

# MAP OF WORLD POPULATION DENSITY BASED ON 312 677 KM² UNIT AREAS (EQUAL TO POLAND'S AREA)

1 : 75 000 000

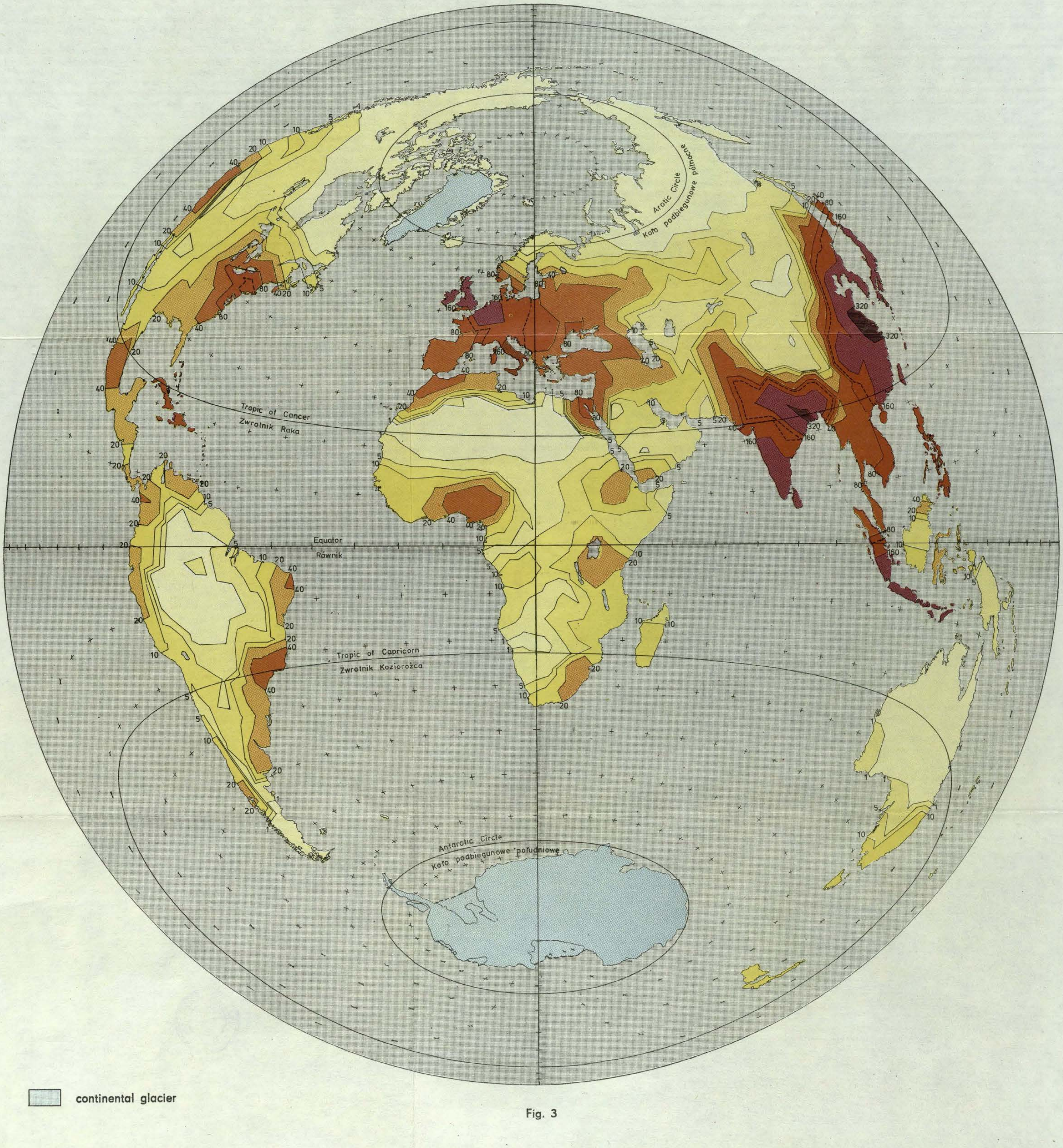


Fig. 3

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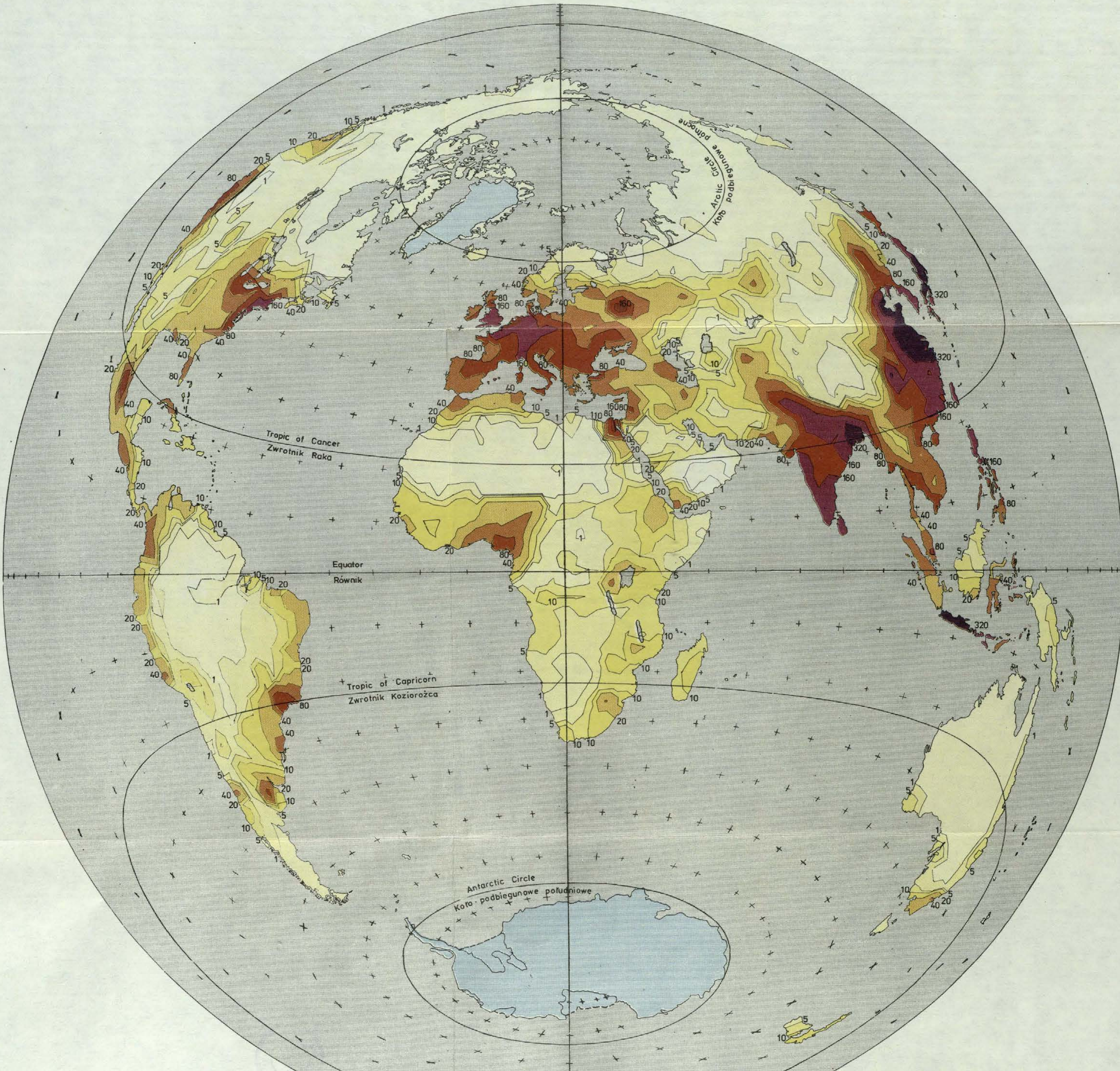
Annex to the article by F. Uhorczak, L. Grzechnik, R Żelasko Geographia Polonica 48, 1982

Ryszard Żelasko

# MAP OF WORLD POPULATION DENSITY BASED ON 100 000 KM² UNIT AREAS

1 : 75 000 000




continental glacier

Fig. 2

0 1 5 10 20 40 80 160 320 640 osób/km²
640 inh./km²

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