Soil Water Problems in Poland

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Before discussing soil water problems, it is first necessary to present a more general background of water economics.

Water economics, after long years of regional traditions, has become a world-wide problem nowadays. A continuous increase in the world population, together with industrial development has increased water demands at a time when land water resources suitable for utilization are gradually decreasing, partly because of water pollution.

Water resources

Despite the fact that land water resources are enormous /$36\text{-}37 \cdot 10^3$ km^3/ and that the uptake of water for human needs does not exceed $6 \cdot 10^2$ km^3, the irretrievable consumption amounts to $1.5 \cdot 10^2$ km^3, so the situation in water economics is not too promising when viewed in the long-term.

The predictions for water consumption in the year 2000 include an annual utilization amounting to 7140 km^3 of which 1090 km^3 will be used irretrievably. The pollution will be equal to 6080 km^3 and as a consequence 37000 km^3 of water will be polluted.

One of the main problems is the utilization of water as a fundamental technological and biological material. Complex analysis and planning are thus necessitated with respect to all water demands and all possibilities of water utilization.

In Europe, where water relations have been most thoroughly investigated, rainfall provides $7320 \cdot 10^9$ m^3 /P = 640 mm/ of water annually. Much of this amount /$4180 \cdot 10^9$ m^3, E = 365 mm/ evaporates, and the rest /$3140 \cdot 10^9$ m^3, H = = 275 mm/ is transported by rivers to seas and oceans.

On analysing these data it is possible to calculate the annual per capita water resources. Poland, Hungary, Romania, West and East Germany and the Benelux countries belong to the group of countries with the smallest water resources in Europe ($1\text{-}1.9 \cdot 10^3$ m^3/person/year).

On the average, Poland receives about 190 km^3 of water yearly, which is equal to 600 mm, and which places the country very low down in the list of European countries with regard to water resources. The greatest amount of precipitation falls in the mountain region in the south of Poland, which has a value of more than 900 mm. In some other places in the northern regions

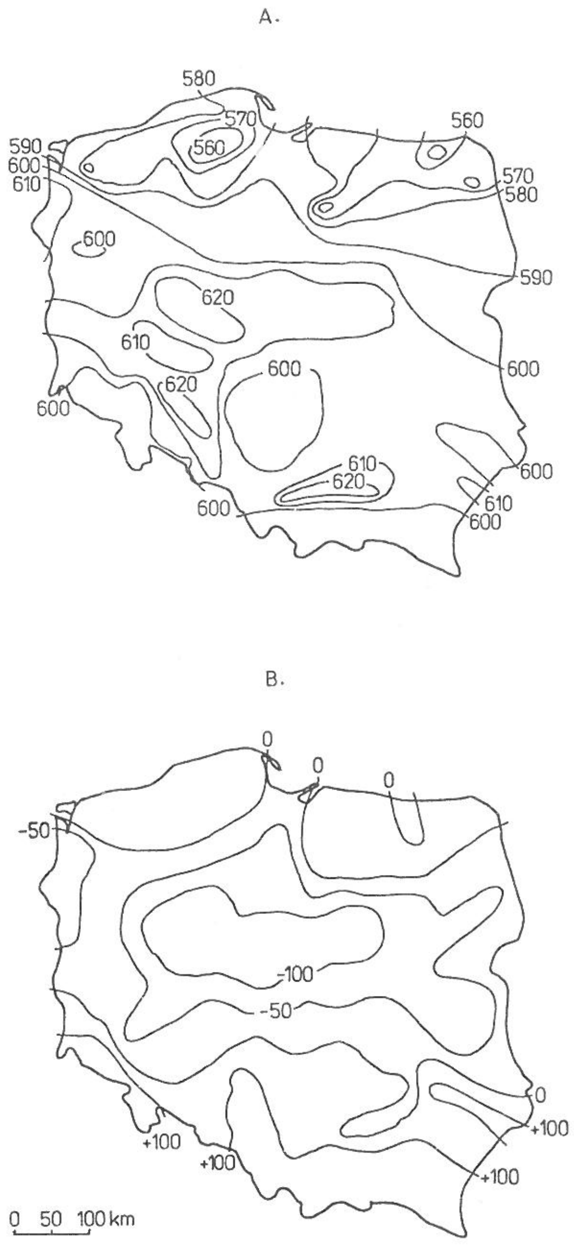
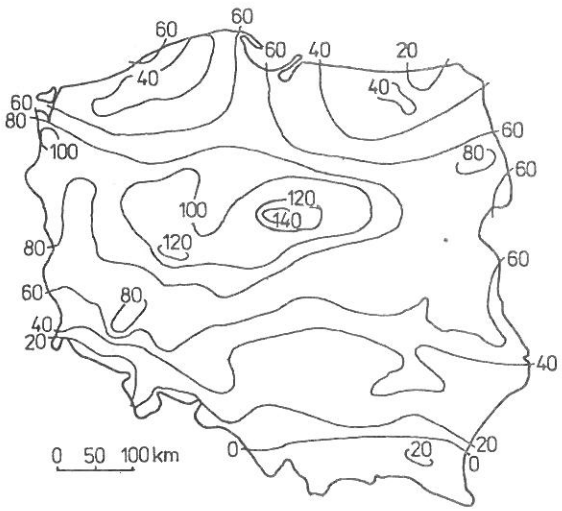


Fig. 1
Potential evapotranspiration (PE) in mm /A/ and differences between precipitation and potential evapotranspiration (P-PE) in mm /B/

A.



B.

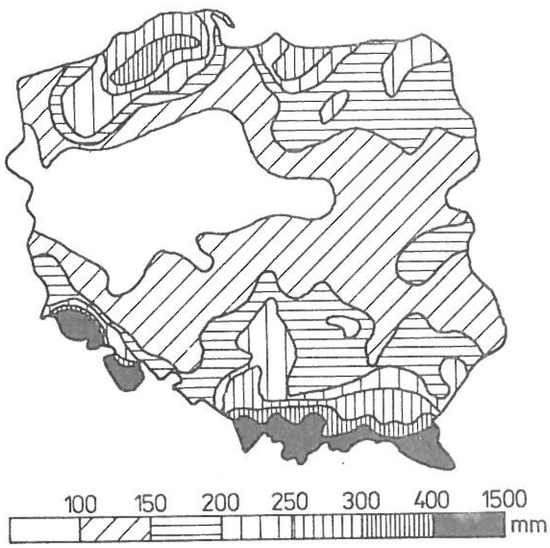
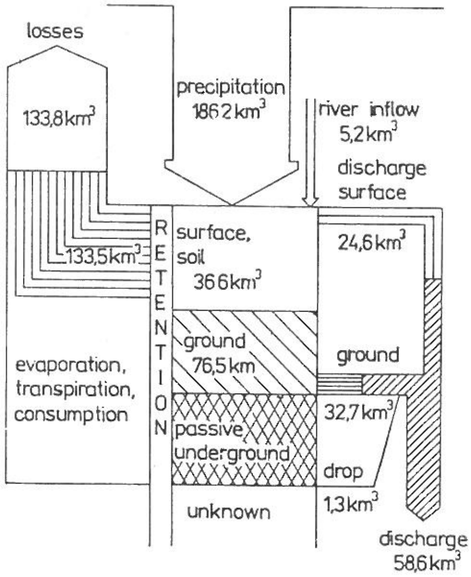


Fig. 2
A. Water deficit in Poland /D = PE-AE; water deficit = potential evapotranspiration - actual evapotranspiration/ in mm. B. Mean water discharge for Poland /30 year average/

A.



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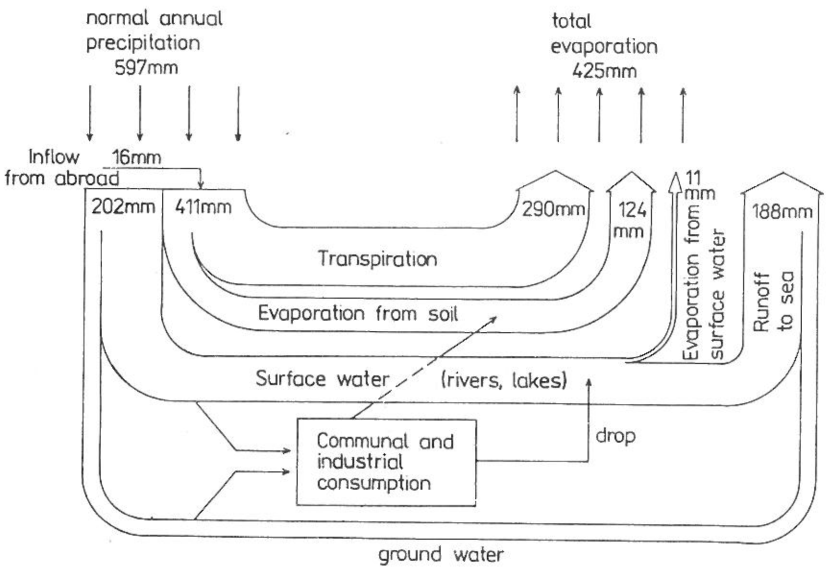

Fig. 3
General water balance of Poland. A. In km^3. B. In mm.

this figure is 700-800 mm. The central part of Poland is the poorest in water resources, due to both a low rainfall rate and to a high degree of evaporation.

The potential evapotranspiration and the differences between precipitation and potential evapotranspiration are shown in Fig. 1 /A and B/.

Water discharge in Poland

A map of water deficits in Poland /Fig. 2A/ has been elaborated on the basis of these data. Fig. 2B shows the mean water discharge for Poland.

Taking into consideration the so-called coefficient of water discharge /water discharge per precipitation x 100/, a value of 25 is found for Poland. This value is much higher in the neighbouring countries. Poland is situated in a water discharge depression area caused mainly by the climatic conditions. In the western parts of Europe the rainfall rate is comparatively higher, decreasing towards the East. Simultaneously, evaporation decreases in the same direction but more slowly, as this is the most stable element in the water balance. As a consequence, in Poland the rainfall is much lower than in Western Europe and the evaporation is fairly high. The continental Eastern Europe zone of low rainfall influences Poland. This is one reason for the low discharge of water. The other reason is the configuration of the terrain, causing a parallel drift of the groundwaters from the Oder river basin to the Elbe.

These anomalies explain why Poland has the smallest amount of water discharge per inhabitant in Europe ($1.7 \cdot 10^3$ m^3/inhabitant/year) while the water discharge in Norway is 115.0, in the Soviet Union 19.0, in Hungary 12.0, in Czechoslovakia 6.5, in France 4.2, in West Germany 3.0, in East Germany 2.1 thousand m^2/person/year, respectively. But even under these unfavourable conditions, the total amount of water at our disposal would be sufficient if the distribution in space and time were satisfactory.

Water balance in Poland

The general water balance in Poland is shown in Fig. 3A /in km^2/ and Fig. 3B /in mm/.

According to calculations made for the River Vistula in Warsaw and the River Bug in Wyszkow, the amount of groundwater feeding these two major rivers constitutes 58% of the total runoff. Taking the same values for the whole of Poland /though this is rather controversial in the case of the River Oder/, it can be estimated that of the annual volume of outflow /58.6 km^3/ about 24.6 km^3 comes from surface runoff and the rest, 34 km^3, from ground outlet. Groundwater gets into rivers mainly in a natural way /32.7 km^3/, whereas the rest comes from wells, mines and springs. About 56% of the total water outflow from Poland comes from the Vistula basin, 30% from the Oder basin and about 14% from the rivers of Przymorze.

Floods

After comparing all the data given above, and analyzing the indices of snowfall /Fig. 4/, mean annual rainfall values, air temperature and the relative air humidity /Fig. 6/, we come to the problem of floods /Fig. 5/. As shown on the map, summer floods appear in the southern parts of Poland and are caused by heavy rain, whereas spring floods, caused by the thawing of snow and by snow and ice congrestions on rivers, appear in the central parts of the country. The appearance of a low water level is also an unfavourable phenomenon as it causes a significant decrease in the river water outflow.

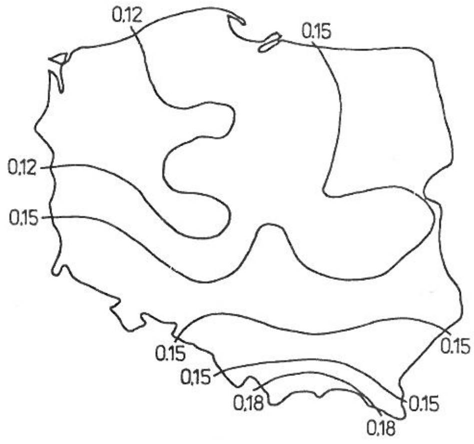

Fig. 4
Snow coefficients /amount of snow divided by annual rainfall/ in Poland

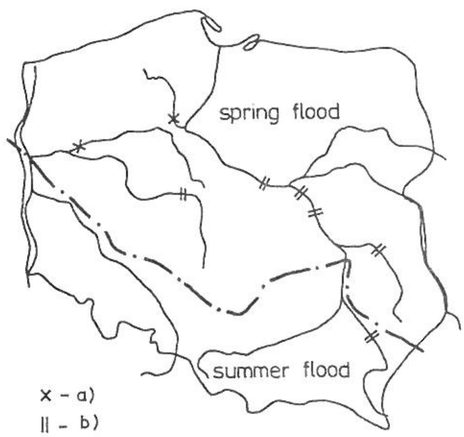

Fig. 5
Floods in Poland. a/ Snow congestions; b/ ice congestions

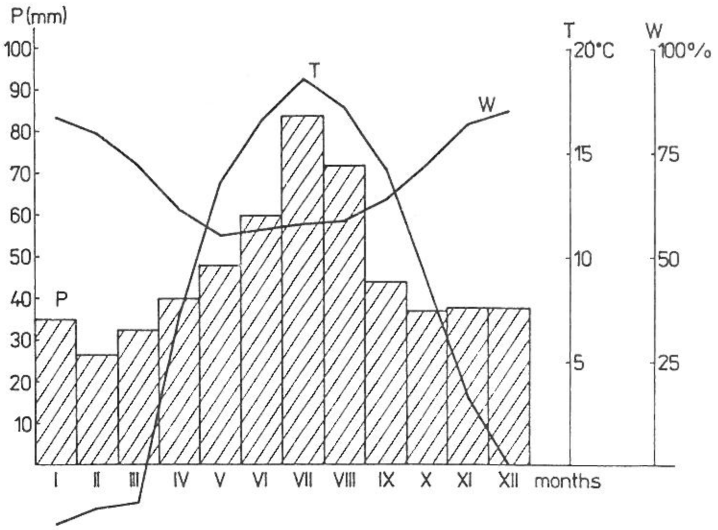

Fig. 6
Mean monthly precipitation /P/, temperature /T/ and relative air humidity /W/ in Central Poland

Water conditions

On the basis of data collected for several years on actual and potential evapotranspiration, rainfall and soil water resources, as well as water deficits and excess a map of water regions /Fig. 7/ has been drawn up.

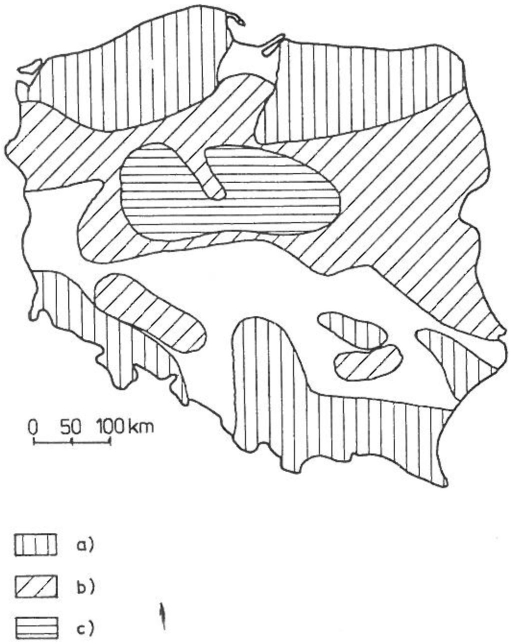

Fig. 7

Water regions in Poland. a/ Regions with water surplus; b/ regions with water deficit; c/ central region with maximum water deficits

By comparing this map with the map of soils /Fig. 8/, where light soils prevail, and with the map showing the duration of the vegetation period /Fig. 9/, a generalized map of the soil-agricultural regions in Poland has been elaborated /Fig. 10/.

The water conditions in the soil environment have been worked out in more detail from the point of view of agricultural production by the Institute of Soil Science and Plant Cultivation in Pulawy. Five categories have been distinguished for water conditions on agricultural production areas:

1. Areas with permanent /frequent and long-lasting/ water excess.
2. Areas with periodical water excess.
3. Areas with an optimum water content.
4. Areas with periodical water shortage.
5. Areas with permanent water shortage.

On the basis of a 10-point scale, in which categories 1-5 were assigned 2.5 point, 6.0 points, 10.0 points, 4.0 points and 1.0 point respectively, an evaluation of the water conditions was made for particular counties /voidvodships/, taking the cooperative farm as the area unit /Fig. 11/.

Fig. 8
Soil map of Poland. a/ Podzolic and brown soils formed from sands; b/ Podzolic and brown soils formed from loams; c/ Podzolic and brown soils formed from silts; d/ chernozems and black earths; e/ rendzinas; f/ alluvial and hydromorphic soils; g/ mountainous soils

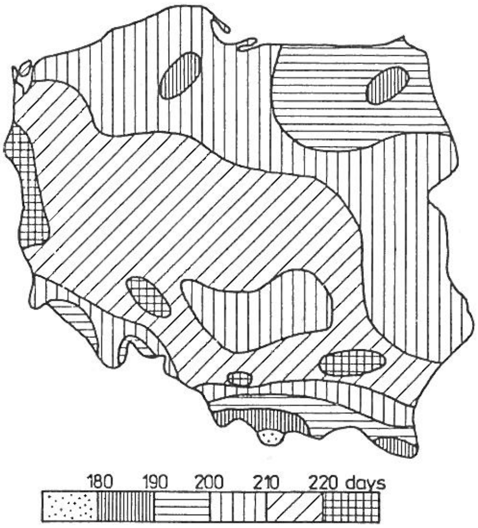

Fig. 9
Duration of the vegetation period in Poland

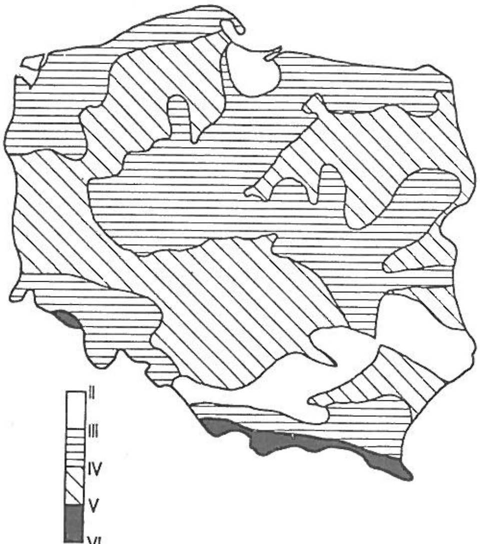

Fig. 10
Soil - agricultural regions in Poland. II-VI: classes of soil productivity from the highest /II/ to the lowest /VI/

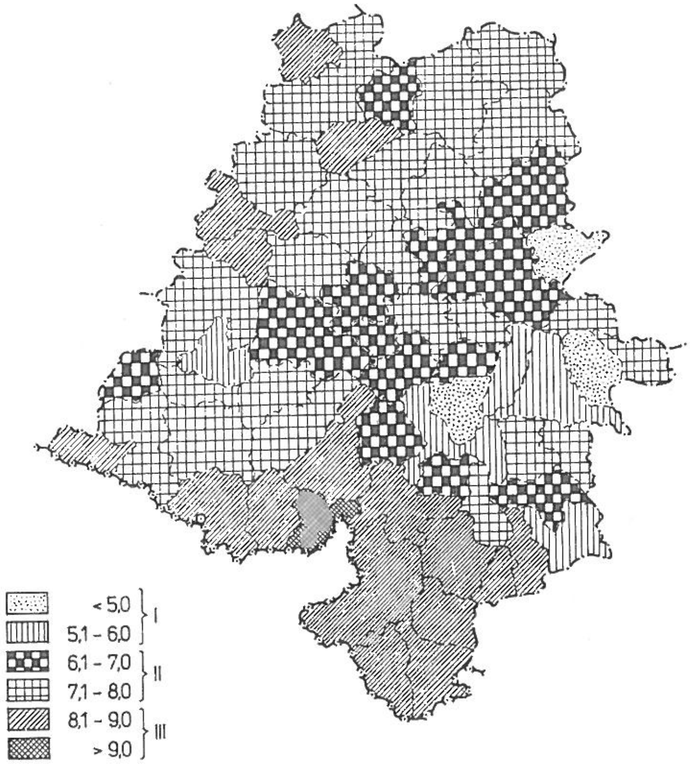

Fig. 11
An example of water categories in a county /voivodship/

Soil moisture conditions

When ranking soil surfaces in Poland according to their water status, 14% of soils were found to be wet, 27.8% too dry and 58.2% of proper moisture content.

To evaluate the dynamics of soil moisture conditions under the influence of industry, three types of soil water management for arable and forest soils have been proposed, on the basis of the groundwater level and water availability to the plant:

1. Groundwater type /GW/: the upper layer of the soil profile is connected with the groundwater table by means of capillary water. Very small seasonal fluctuation in the groundwater table.
2. Rainfall-retention type /OR/: plants are dependent only on the rain.
3. Rainfall-groundwater type /OGW/: this is intermediate between GW and OR.

The climatic conditions, as well as the regulation of rivers, the destruction of small dams, excessive deformation, improper drainage and the large-scale use of water for industry, mining and municipal purposes, are the causes of the water deficit facing agriculture.

The characteristics of soil moisture for plant production have been well elaborated by the Institute of Meteorology and Water Management in Warsaw. These include the frequency, range and duration of unfavourable soil moisture conditions during the vegetation period /from April till October/. The results obtained over a 15-year period may be useful in the evolution of plant vegetation conditions and in the planning and execution of field work, as well as in the planning of soil amelioration and in the determination of irrigation periods.

The analyses were based on visual assessments of the moisture status of the surface soil horizon according to a four-level scale: during the 10-day period the soil moisture was excessive, sufficient, insufficient or disastrously low.

To start with a determination was made of the relative frequency of 10-day periods with excessive or deficient soil moisture over the whole of Poland, and in the particular reporting regions individually for winter cereals. An analysis was made of the range of unfavourable soil moisture conditions during 10-day periods, months, and the major development phases of the plants. The duration of soil moisture deficits and excesses was also studied.

The data in Figs. 12 and 13 show that under the soil-climatic conditions of Poland it is possible for either excessive or deficient soil moisture to occur in any 10-days during the period from April to October.

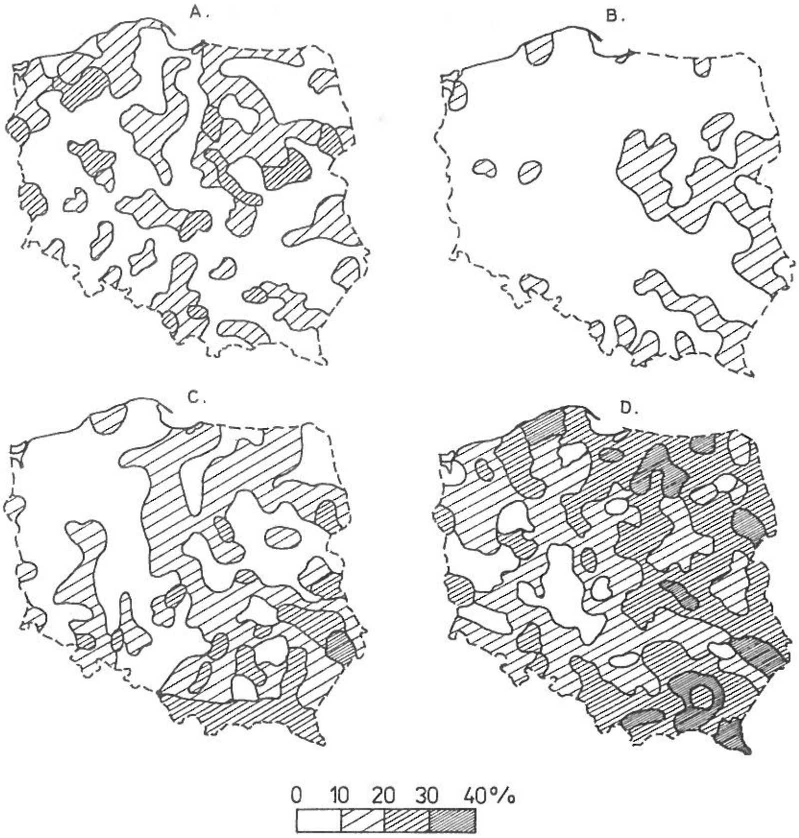

Fig. 12
Areas with frequent occurrence of 10-day periods with deficient soil moisture. In: A. April. B. May. C. June. D. August-October

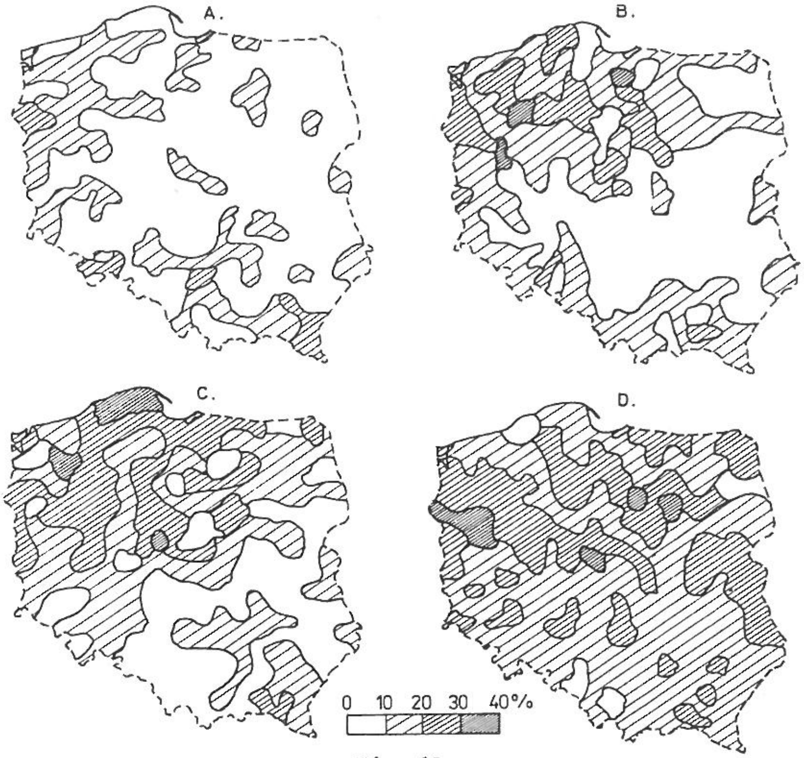

Fig. 13

Areas with frequent occurrence of 10-day periods with excessive soil moisture. In: A. April. B. May. C. June. D. August-October

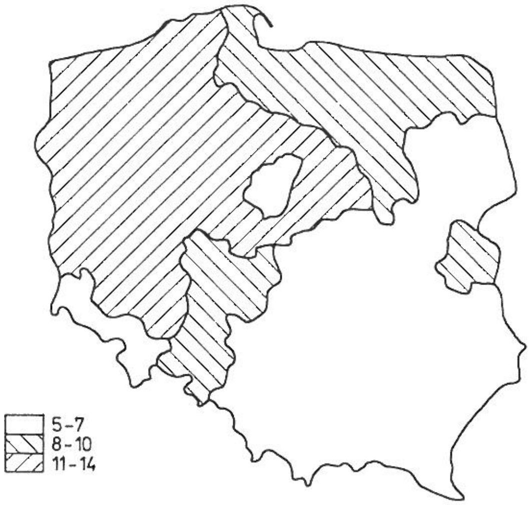

Fig. 14

Number of 10-day periods with insufficient soil moisture

Soil droughts, however, are observed much more frequently and cover considerably greater areas than excessive soil moisture /Fig. 14/. This is related to the low water retention capacity of Polish soils, and to their tendency to dry rapidly.

The frequency of 10-day periods with soil drought increases from April to August, and then, from August to October, decreases to the initial level observed during the spring /Fig. 15/.

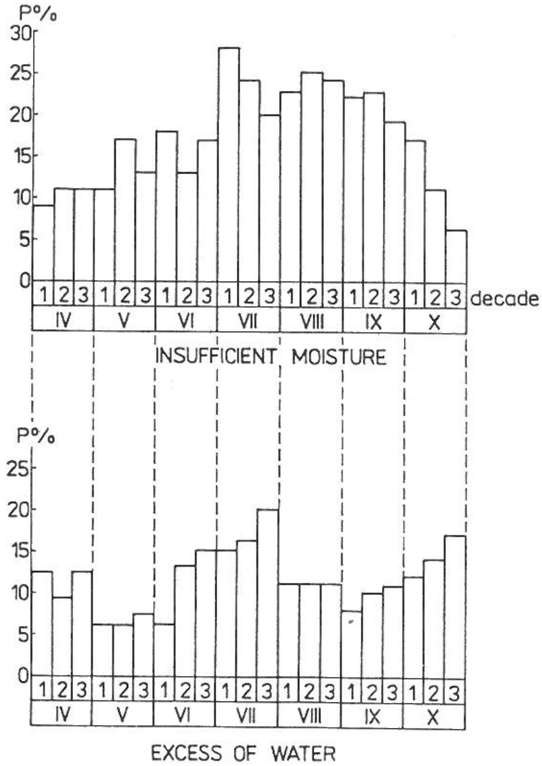

Fig. 15
Frequency of occurrence /0/ of 10-day periods /1, 2, 3/ with insufficient and excess water in the soils

Land amelioration

After the Second World War, about 6.5 million hectares of arable land in Poland needed amelioration /mainly drainage but also irrigation/. Now, to be independent of seasonal shortages or excesses of rainfall water, drainage is necessary on the surface of about 4 million hectares /from a total of 15 million hectares of arable land/ and irrigation on about 1 million hectares of grasslands /from a total of 4.5 million hectares/. Amelioration is followed by the lowering of the shallow groundwater level from about 0.5 to 1.0 m.

The large-scale use of sprinkling irrigation for cultivated plants is not predicted, except where there is intensive agriculture /mainly horticulture/ and enough water. For this purpose it is necessary to use models including soil conditions, climatic conditions and the water requirement of various plant species, even in various phases of their growth.

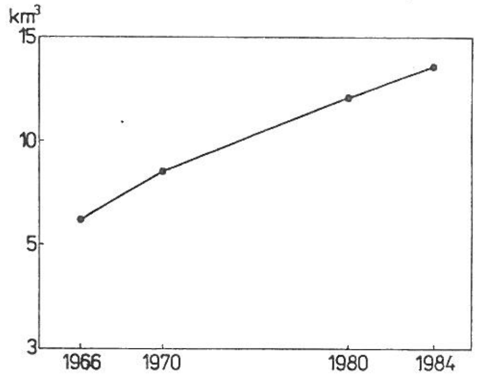

Fig. 16
Industrial wastes drained off to surface waters

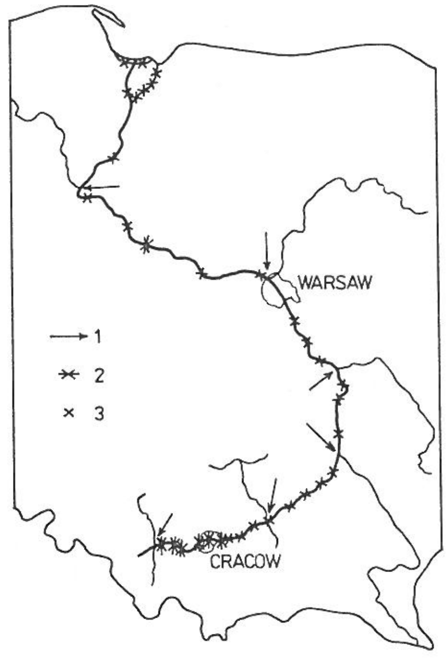

Fig. 17
The River Vistula with a system of steps and main tributaries

Water pollution

The problem of water pollution in Poland is as important as in any heavily populated and highly industrialized country. Fig. 16 gives an example of the increasing amount of industrial waste drained off to surface waters.

Vistula program

Elaborated in 1979, the Vistula programme was aimed at the complex regulation and management /for industrial, agricultural and transport purposes/ of the resources of the greatest Polish river /the Vistula/ and other water resources of the country. It included the building of a system of 28 steps along the entire length of the river /950 km/, 18 large water reservoirs and several hundred smaller ones /Fig. 17/. There were also plans to transport water from the Vistula to other regions of the country. Now, the realization of this very ambitious programme is dependent on a better economical situation in Poland.

Conclusions

The basic aspects of water economics in Poland can be divided into groups:

1. Quantitative and qualitative protection of water resources
   a/ protection from unfavourable changes in water balance;
   b/ protection from excessive exhaustion of groundwater resources, which are very difficult to renew;
   c/ protection of waters from pollution.

2. Improving the water balance by influencing various stages of water circulation by:
   a/ minimalizing unfavourable processes such as useless evaporation or surface flow-off;
   b/ maximalizing favourable processes such as percolation, increasing retention, especially underground, regulation of surface runoff;
   c/ planning agrotechnical and phytoamelioration treatments, including activities directed at appropriate water economics.

3. Socially correct utilization of water resources
   a/ proper hierarchy of water demands;
   b/ rational planning in water investments based not only on economical and technical criteria but also on biological considerations;
   c/ authorizing only the most effective methods of water utilization.

The general problems of water economy significantly influence the soil water status with all consequences but they are also important in some regions for the maintenance of farms and for animal breeding.

Summary

Water resources and their balances in Poland are shown in this study against the background of neighbouring countries. The causes of water deficits are also mentioned, together with the problems of land reclamation and water pollution.

The paper is illustrated with 17 figures.