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THE AGRO-HYDROLOGICAL SURVEY OF THE NETHERLANDS

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SUMMARY

For the conditions of climate and groundwater depth, as are prevailing in the Netherlands, a system to describe the agro-hydrology of the country was worked out. The system seems adaptable to other climates, provided the land is sufficiently flat and the groundwater level not too deep.

With the simple means of collecting data on water table depth, salt content of open water and of the existing practical experience of the farmers with respect to drainage or drought problems, a deep insight in the agro-hydrology of large areas may be obtained. The resulting maps may assist general planning of hydrological improvements and may serve as a basis for the execution of local projects.

It was possible to collect a vast amount of material by organizing a voluntary co-operation with state and provincial agencies, catchment boards and individual farmers. It is of utmost importance that the central experts not only use their time in organizing the work, classing the data and constructing the maps, but also to study the data in their mutual relationships.

The work resulted in a number of maps for the whole of the country and many frequency distributions of the collected data as water table depth, salinity, drainage or desiccation problems, yield depressions, grass-land-arable land ratios and so on. The detailed study of the results revealed, that comparison of drainage—or drought evaluations with water table depths may yield results of the same type as a vast field experiment. Comparisons of water table depths with rainfall and calculated evaporation gives an insight in the water-balance as otherwise only a much more intensive study might have given.

By combining a survey with closer study of the data, it is possible to simplify the type of the observations needed, to give them the right place in the land improvement project and arrive at a better approximation of the economic optimum of improvement measures.

RÉSUMÉ

Un système de description agro-hydrologique du pays a été mis au point pour les conditions climatiques et les profondeurs de la nappe souterraine existant aux Pays-Bas. Ce système semble pouvoir convenir à d'autres climats, pourvu que le pays soit suffisamment uni et que la nappe souterraine ne soit pas trop profonde.

Des moyens simples comme le rassemblement de données sur la profondeur de la nappe souterraine, le degré de salinité de l'eau de surface et l'expérience pratique existante des paysans en ce qui concerne les problèmes de drainage ou de sécheresse, permettent d'obtenir une connaissance profonde de l'agro-hydrologie de régions étendues. Les cartes qui en résultent peuvent aider à établir des projets d'amélioration hydrologique et servir de base à l'exécution de projets locaux.

Il a été possible de rassembler de très nombreuses données en organisant une collaboration volontaire avec des services nationaux et provinciaux, les comités de direction des polders et avec des fermiers individuels. Il est de la plus haute importance que les experts remplissant une fonction centrale ne s'occupent pas uniquement de l'organisation des travaux, du classement des données et du dressage des cartes, mais aussi étudient les rapports existant entre les différentes données.

Les travaux ont donné un certain nombre de cartes pour le pays entier et de nombreuses distributions de fréquence des données rassemblées, telles que la profondeur de la nappe souterraine, la salinité, les problèmes de drainage ou de dessèchement, les récoltes insuffisantes, les rapports herbage/champs cultivés, etc. L'étude détaillée des résultats a révélé que la comparaison entre les évaluations de drainage ou de sécheresse et les profondeurs de la nappe souterraine peut fournir des résultats analogues à ceux d'un vaste essai en plein champ. En comparant les profondeurs de la nappe souterraine aux données sur les précipitations et l'évaporation calculée, on peut obtenir de l'hydrologie d'une région une connaissance qu'autrement, seule une étude bien plus approfondie aurait pu fournir.

En combinant l'aperçu et une étude plus approfondie des données, il est possible de simplifier le type d'observations nécessaires, de leur assigner leur place correcte dans le projet de mise en valeur des terres et de parvenir à une meilleure estimation de l'optimum économique des mesures de mise en valeur.

1. Introduction

An investigation into the depth of the watertable and the effect thereof on the productivity of the soil was executed over nearly the entire area of the Netherlands. A number of 25.000 observation wells were installed, the existing experience with respect to drought resistance of the land was collected, and the observations concerning the reaction of the crop on groundwater depth from the total experimental material present in the Netherlands was condensed to a general scheme. A soil map and a map of salinity of open water were made, data on cropping systems and on productivity of the land were brought together. From this vast material an agro-hydrological description for the whole country and calculations on the loss of crop yield through excess of water or drought were made and published in 12 volumes (*).

2. The motive

The Netherlands came out of the ravages of the war with a rather damaged production apparatus. Over the whole country, the population experienced a strong urge to reconstruct and improve wherever this was possible. Everybody was ready to go to great exertion, everything should become better than it had been before. The agriculture was possibly least damaged and in the first years after the war a large part of the export was formed by agricultural products. When in 1947 agriculture was hit harmfully by the very dry summer, the economy of the Netherlands was hit at the point where it was at that time rather vulnerable. When in 1949 the drought repeated itself, it was a matter of course, that much thought was given to the possibility to manage the water in such a way, that the highest crop yield should be assured, whatever the weather might be.

In 1949 a proposal was handed to the Central Organization for Applied Research—the «Landbouworganisatie T. N. O.»—to promote a nation-wide survey with respect to the water relations in the agricultural areas of the country. Due to the Marshall scheme, the necessary funds could be provided for and a highly trained staff became available due to the return of large numbers of experts leaving the Netherlands East Indies.

When the investigations advanced, the background for the survey in the Netherlands changed gradually. The weather in the following years was distinctly wetter than normal. As a mean over the following 8 years the rain exceeded the 100 year mean by 55 mm. The interest changed from application of water in dry periods to the age old aim of removing excess of water. The industry prospered, the rehabilitation of the country came to its close and eased the situation on the import-export balance. The production of agriculture lost its preponderant position of the first years after the war. Wages went up and agricultural prices remained the same, so what was considered economical directly after the war no longer remained so. When in 1959 the report of the survey—the C. O. L. N.-report—was published, it was looked upon more as an inventory of water relations in the Netherlands than as a general plan for a future scheme of comprehensive water management practices.

(*) De Landbouwwaterhuishouding van Nederland (General report and eleven provincial reports). Commissie Onderzoek Landbouwwaterhuishouding Nederland T.N.O., The Hague, 1958.

Circumstances changed and so did the significance of the survey. But circumstances may change back. We know of a period of 20 consecutive years with a mean rainfall of 150 mm. less than in the 8 years of the hydrological survey. Under such circumstances the significance of a water management scheme might differ strongly from the significance of such a scheme in a wet period.

The future development of water control will depend on the economic framework of national, European and world agriculture. Within this framework a complete review of the frequency of rainfall deficits and of their impact on farming will have to be the basis of the decision on the application of economic methods of supplemental irrigation.

3. The aim

It was generally felt, that a description of the water relations should start with an investigation into the loss of yield by excess or shortness of water. Under the climatological conditions of the Netherlands a deep rooted crop will give good yields on a good soil even in dry years. The productivity of crops with a shallow root system and of crops on shallow soils depends on the presence of a high water table. Because the larger part of the Netherlands soil has such a shallow water table that the crop may make good use of the water stored as free water, this meant a survey of the depth of the water table. This survey resulted in a map for the water level in early spring and at harvesting time, for convenience called the maps for the water table in summer and in winter. But also the water storage above the water table was important. A soil map was needed to give an impression of this important aspect of the moisture relations.

In order to deduce from these data the loss in yield, a first step was to derive a map, giving the farmers' experience with relation to drought effects in his crops. At the same time, a vast survey on the productivity of the soils all over the country executed with more than 3.000 field experiments by one of the collaborating institutes, offered itself for use to check the judgment of the farmers and gave the opportunity to gauge these experiences in terms of weight of yields. At the same time good use could be made of results of previous experiments on the influence of soil type and groundwater depth.

Parallel to this quantitative description of the water relations, a vast amount of information was collected on problems of hydrology, results of management by catchment boards, land use problems in relation to the water management and so on. In a country as the Netherlands much information is already available in print, and this needed not to be inserted in the report. A number of situations, however, harmful or advantageous to agricultural production and not already printed elsewhere, could be embodied in the description of the hydrological situation in the 12 volumes mentioned.

4. The organization

The organization of an investigation as mentioned above, has to be able to cope with the special conditions that the larger part of the work requires activity only a few days a year. In this case 23.000 observation wells were read four times a year, and 2.000 wells twice a month. Each research worker could spend only a limited amount of working hours on his group of wells. Here one had to rely on voluntary co-operation of others. The mapping of the drought sensitive fields could be done best by people with a broad local experience. Here co-operation of a voluntary nature was necessary too. All kinds of further aid were necessary. A central policy committee was therefore set up, of which high officials of the Ministry of Agriculture and the Ministry of Public Works were member. A technical committee with members from the divisions of Agriculture, Horticulture and Land and Water Management of the Ministry of Agriculture, of the Ministries of Health and of Public Works, of the Agricultural University and of a number of experiment stations and research institutes as the Central Institute for Agricultural Research, the Experiment Station for Arable and Grass-land, the Institute for Soil Mapping, the Institute for Civil Water Supply, the Research Department of the Zuiderzee Works and the Royal Meteorological Service, was installed as a national group to promote the technical co-operation. In the 11 provinces of the country provincial committees were set up, with members of provincial branches of the Ministry of Agriculture and the Provincial Public Works, to support the execution of the work. In each province the work was co-ordinated by a graduate expert, attracted for the purpose of this work as representative of the national technical committee.

Co-operation on a national level with the various institutes mentioned before, provided important data like a soil map of the Netherlands, productivity data of a set of 3.400 plots, results of previous experiments on groundwater depth, salinity measurements, meteorological data, altitude measurements of the upper edge of the observation wells and so on.

This organization of co-operating agencies provided the investigators with every desired information available in the country. The habitual friendly and active co-operation between ministries, departments and institutes in the Netherlands proved to be very valuable for the development of the project.

5. The observations

The aim was to make a map of the water table depth and a map showing the loss of yield due to the depth of the water table and the moisture retaining capacity of the soil. The water table was daily observed on 65 points of the first order. Here also rain and evaporation were measured. On 2.000 points of the second order the water table was read every fortnight. The points of the third order, 23.000 in total, with a density of one well on 100 hectare, were read four times a year. The wells consisted of 6 drain tiles, inner diameter 5 cm., put in the soil as a vertical tube, this being the easiest way to construct the wells. This construction was cheap and easily repairable. The possibility to find the place of a damaged or disappeared well quickly was important, 6% of the wells being out of order every three months. Test wells near built-up areas or near the entrance gate of fields proved to be very vulnerable. The observations were made by 2.000 voluntary observers.

The drought sensitivity of the field was judged by personnel of the agricultural advisory service, with about 500 advisory assistants co-operating. The main difficulty was to get the observations expressed in the same scale. The provincial representatives were responsible for a uniform evaluation of the drought sensitivity. In many discussions between the representatives and with the provincial assistants of the advisory service the homogeneity of the observations was perused. A reference scale was obtained by evaluating the 3.400 productivity plots mentioned before. This provided a means of correction of the provincial level of the drought sensitivity evaluation.

A great many further data proved to be necessary. The soil map of the entire country was finished in this period and provided a division of the soil in 250 different profiles, a number too large to use in this study. The profiles were therefore condensed to 7 more or less uniform agro-hydrological groups. They range from light soils with great sensitivity for deviations from the required shallow water depth to heavy soils requiring deep drainage and with small sensitivity. A map giving the permanent grass- and arable land was made from ordnance-maps and field observations. The cropping system could be taken from data of the Bureau of Statistics. The determination of the salt content twice a year provided extremely valuable data for that part of the country where horticulture needs fresh water so badly.

The experience has shown, that the provincial representatives needed nearly all their time to control and repair observation wells and correlate the data on drought sensitivity. During the three years of observation hardly any time was available for study of the results. This study had to come afterwards and it was proved again that one may count upon as much time necessary for study as for the collecting of data.

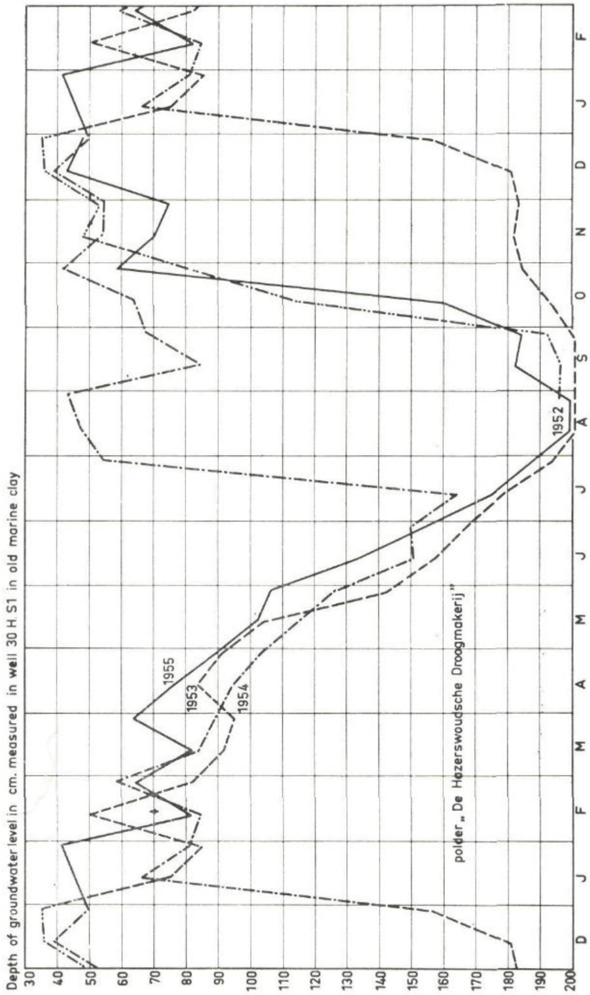

Fig. 1 — The lowering of the water table in spring increases in a very similar way in successive years. The variation is situated in the beginning of the autumn rains. Winter- and summer level together may describe the variation of the water table for agricultural problems with sufficient accuracy

6. The results

The construction of a map of the water table depth was made easier to a great extent when it was proved, that over the whole country the time-depth curves for the successive years did have approximately the same shapes, see fig. 1. If the ground-water depth is known in the winter period and for harvesting time, the depth at moments inbetween can fairly accurately be predicted.

The winter- and summer water depth maps were constructed therefore and care was especially taken to make the maps comparable for the whole of the country. Afterwards a number of observations were collected at various places and compared with the description on the map. An error of 25 to 30 cm. was found, presumably as a consequence of the variation in altitude of the soil surface over short distances. The use of aerial photographs have aided considerably in obtaining this good result, because slight differences in colour could be used as delimitation of dry and wet parts of the land.

TABEL I

SUMMER LEVELS

Province	Depth in cm. below soil surface						
	0-20	20-40	40-70	70-100	100-140	140-200	> 200
Groningen	–	0	7	25	38	25	5
Friesland	–	3	25	18	29	22	3
Drente	–	2	21	20	22	22	13
Overijssel	–	1	12	24	34	25	4
Gelderland	0	0	11	13	25	37	14
Utrecht	–	2	28	27	21	15	7
Noordholland	–	1	21	30	30	15	3
Zuidholland	–	1	23	26	24	24	2
Zeeland	0	1	5	11	31	44	8
Noord-Brabant	–	0	4	14	28	34	20
Limburg	0	1	5	7	15	25	47
The Netherlands	0	1	14	19	28	27	11

The measurements of the water table add up to the picture—given in Table 1 for the eleven provinces—that the main water depth, taking into account the large percentages in the groups 100-140 and 140-200 cm., is about 140 cm. below soil surface, a depth which is on sandy soils too great for maximum agricultural production.

The calculation of the loss in yield proved to be far more difficult. The water depth had to be translated into loss in yield with isocarp diagrams, specially constructed for the occasion, which showed the relation between the yield decrease and the winter- and summer water table as independent variables, see fig. 2.

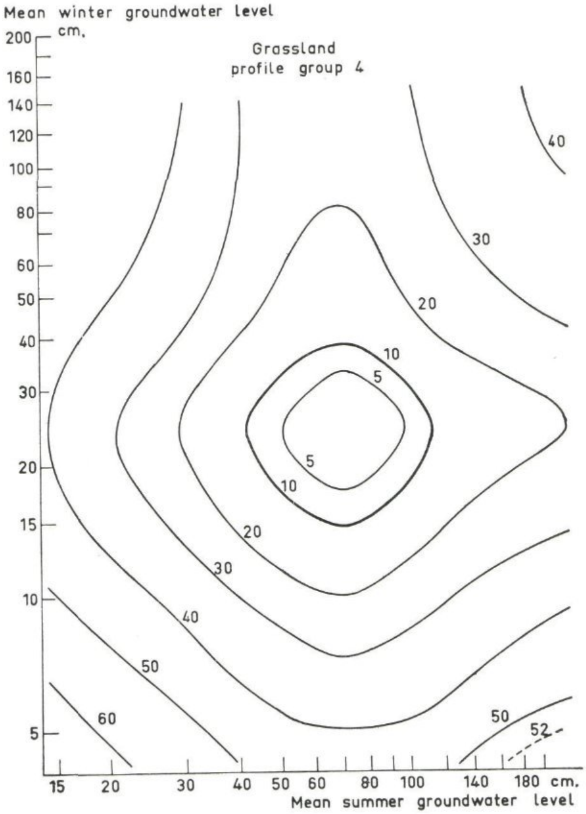

Fig. 2 — The relation between the decrease in yield and the spring- and summer water level is given by the isocarp diagrams, which vary according to crop and profile

This result was compared with the results calculated from the drought sensitivity evaluations and the known yield of the productivity plots. Here also a fair amount of checking, correcting and fitting of curves was necessary to allow for local variations in cropping system, evaluation of drought and so on. It was proved that the judging of drought sensitivity in first class agricultural areas was far more severe than in areas, where people were accustomed to excess or lack of water. The comparison of the two approximations showed that an error of 10% for the mean value of loss in yield for areas of some 25.000 ha has to be expected, see fig. 3.

If the loss in yield was split up into areas with less than 10% decrease and more than 10%, either through excess or lack of water, a triangular diagram did prove that there is a distinct relation between these three groups. In fig. 4 the observations are given for a very dry, deeply drained province.

If these data from the triangular diagrams, for the whole country, are combined for different profiles, a clear indication is obtained on the limit of productivity, as far as it is influenced by the depth of the water table, to be reached by the present methods of land drainage. The optimum yield—often more than 10% below the level that is physiologically possible—depends on the variation in altitude of the land and the

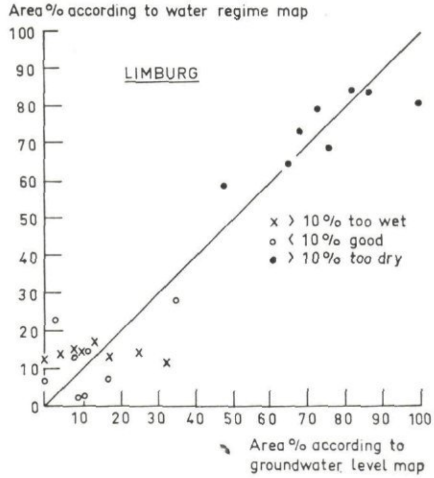

Fig. 3 — The area with a decrease in yield of 10% or more, specified with respect to deficient drainage or drought, derived from the farmers experience and from groundwater depth, and isocarp diagrams compare rather well

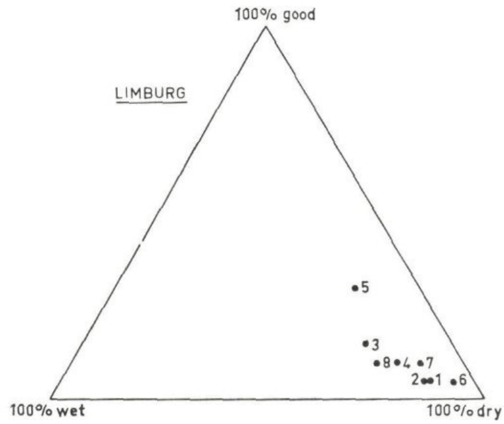

Fig. 4 — In a triangular diagram the observations of the water management situation of different areas—depicted with their area number—are situated on a certain locus. This means in this case that building up of the water table in a dry region at once, will produce wet spots even if the main area is still too dry

sensitivity of the profile to changes in the water table with respect to their productive capacity, see fig. 5. Peat, though in most cases a rather flat soil, is very sensitive to variations in water depth and shows a low optimum yield. The Limburg sand, through only of a medium sensitivity, is very uneven in topography and shows also a considerable loss in yield. These losses in yield may be decreased by changing over towards smaller drainage units than are customary at present. The provincial reports deal with these problems of more local importance.

TABLE II

Areas in per cent of the provincial area included in the classes of yield depression, that were calculated as averages of the drought estimation and the groundwater level measurements

Province	Depression of more than 10% resulting from excess of water	Depression below 10%	Depression of more than 10% resulting from lack of water
Groningen	19	55	26
Friesland	31	42	27
Drente	19	29	52
Overijssel	17	32	51
Gelderland	14	39	47
Utrecht	27	35	38
Noordholland	24	54	22
Zuidholland	21	56	23
Zeeland	8	45	47
Noord-Brabant	13	40	47
Limburg	13	9	78
The Netherlands	19	41	40

All the data on depressions in the yield capacity depending on the excess of water as well as on the lack of water, have been brought together in Table 2. For each province the percentage of area in the wet, good and dry classes are given. Friesland —the main grass-land area—is wettest and Limburg on the transition to the Belgian Ardennes and the German Eiffel is dryest. As can be seen, a greater part of the Netherlands is subjected to drought than has excess of water. The drainage depth, required for the lower parts of an area, has had the consequence that the higher parts have a water table which is too deep. The problem of supplemental irrigation in the higher lands has arisen as a consequence of the drainage work in the lower land of the areas, as can be testified by fig. 5.

7. Further developments

The extensive material of data on water table depth, yield capacity, farming system, soil profile, drought sensitivity and so on, is a storehouse of problems, which are waiting to be solved by anyone who feels inclined to study this material in greater detail.

In fig 6, taken from the report of Zuidholland, is shown how the percentage of permanent grass is affected by the groundwater depth in summer and winter. This kind of probability diagrams was made for many combinations of variables and gave a deeper insight in the way in which practical agriculture reacts on favourable or unfavourable circumstances, as water depth in winter and summer, soil profile, etc. This may be developed into a hydrological land use classification with quantitative criteria for its mean values as well as for the often very important indices of its variations.

A few results may show the type of problem, which may be solved when ground-water—and ditch-water levels are available over a sufficiently long period, for example over two to three years with weekly or fortnightly readings.

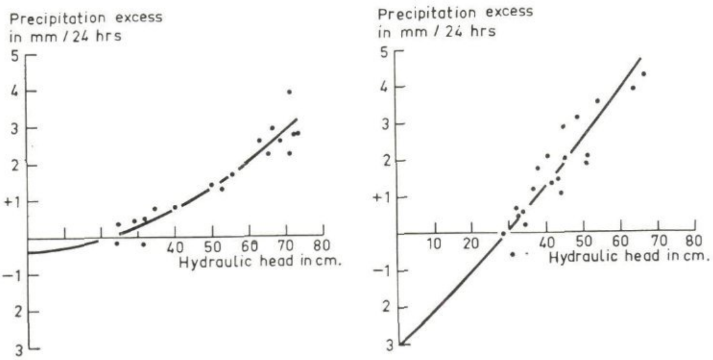

Fig. 8 — The water table depth correlated with rainfall excess, yields a discharge curve. By fitting a drainage formula, hydrological constants may be derived. Two cases of seepage are demonstrated, where extrapolation of the drainage curves to a pressure head of zero cm., gives the intensity of seepage

In fig. 8 a diagram is shown where, for the nearly evaporation-free winter months, rainfall is plotted against pressure-head after correcting for storage variations as they appear in water table fluctuations and correcting for the small influence of evaporation. Two fields are situated near the sea in a deep polder while seepage into the polder takes place. The graph shows how a drainage discharge curve can be found and how from the pressure head at a zero rainfall excess the seepage at the place of measurement may be concluded. Seepage is often a difficult problem but with water depth data it can be solved in a simple way.

In fig. 9 it is shown how the values for storage capacity—found by plotting, for the same mean pressure head, the increase or decrease of the water table depth against the excess of rainfall over evaporation—are plotted against the depth of the water table and the amount of water penetrating into the soil or rising to the surface by means of capillary activity. Determination of the water table depth gives a very complete picture of the moisture retention under certain circumstances.

Fig. 10 shows how the real evaporation is a function of the calculated evaporating capacity of the atmosphere Eo and the rainfall. In the upper figure the curve is drawn for an excess of precipitation of 5 mm. per ten days. This real evaporation can be calculated if run-off and storage are known, real evaporation remaining the only term in the equation of the water-balance which is unknown. The value can be calculated. With this calculated evaporation and with values for rainfall and groundwater depth, the curves may be constructed by fitting the data mentioned in such a way, that a more precise relation between the evaporating capacity Eo and the real evaporation is obtained. Corrected data for the calculated real evaporation may be taken from the graph. This corrected quantity for the real evaporation has therefore not the character of a residual entry as often is the case with the evaporation data, but approaches the accuracy of a direct solution.

The water table determinations do not give a picture of a part of the hydrological situation alone and they must not be judged only on their direct and most obvious value. Where the water table is shallow or moderately deep—down to two meters—a lot of basic information on the hydrological properties and reactions of the profile and the location where these parameters are valid may be obtained from it. Where

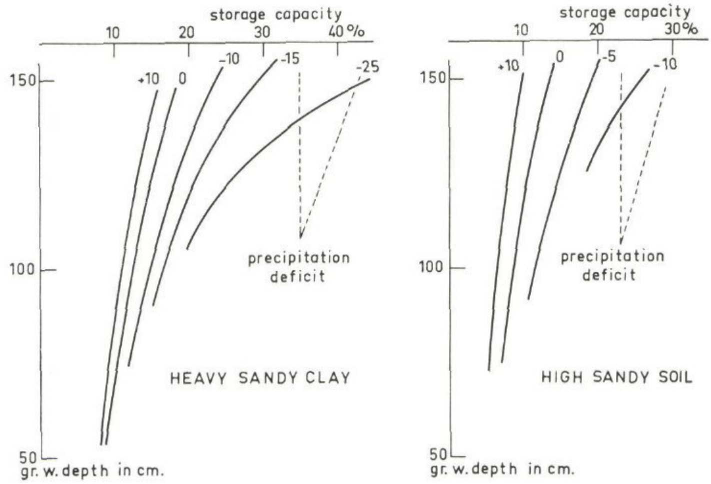

Fig. 9 — The observations of the water table lead to an insight in the storage capacity. This storage capacity is a function of groundwater depth and excess of rain or evaporation. Results are given for a clay- and a sandy soil

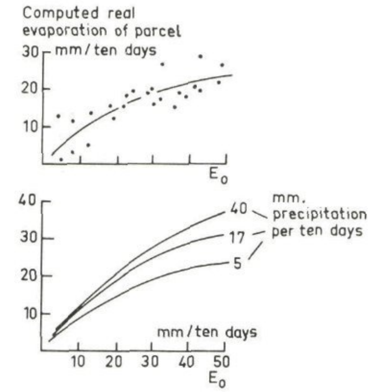

Fig. 10 — The observations of the water table, compared with the calculated evaporation Eo, give an insight into the real evaporation which is influenced markedly by the rainfall. In the upper graph the curve for an excess of precipitation of 5 mm. per 10-day period is drawn. Every observation well with not too deep water may give results which normally would require the use of a lysimeter

the C.O.L.N. survey has provided the Netherlands' hydrologist with 2.000 points from which these properties and processes may be evaluated and data of more than a 1.000 other points are available from other investigations, the basic material is available for a type of quantitative hydrological description of the country, which in any other way would be difficult to achieve. The work of the C.O.L.N. has urged the hydrologists in the Netherlands to a considerable activity. And one wonders, even in view of the changed circumstances regarding the significance of agriculture for the prosperity of the population as a whole, whether the technical expert of the near future might not find in the C.O.L.N. survey a means of transforming the Netherlands into an even more opulent agricultural area as practical experience already succeeded in establishing.