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A test considering the possibilities for application of a theoretical optimalization approach in water management design practices.

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List of contents

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INTRODUCTION

One of the main factors influencing crop growth and yield is the available moisture capacity in the root zone. The moisture holding capacity of the soils differs largely, concerning the type of soil (its physical properties and chemical constitution). The water deficiency, due to evapotranspiration, can be supplied to the soil either by the underground water, through the capillary rise, or by natural or artificial precipitation. So, the optimal moisture content required by the plant, can be controlled either by the depth of the groundwater table or by the amount of precipitation or the supplied irrigation.

In most parts of the Netherlands, there is no need for additional artificial water supply, in order to cover the consumptive use of the plants.

That is not the case in the slightly undulating sandy soils of the south-eastern part of the country, where moisture conditions are often insufficient during summer time, so a water supply is required.

As it is pointed out (VISSER 1964) in the Netherlands the agricultural advantages due to improvement of the water conditions, even in a desiccating land, are very modest and often dubious. The productive capacity of the soils is already very near to the optimum.

A theoretical elaboration about the optimal water management in an undulating sandy soil, was carried out by the Instituut voor Cultuurtechniek en Waterhuishouding (I.C.W.) initiated and coordinated by Ir. W.C.VISSER (1964). As a pilot plant, an area, namely the "Deurne Project", situated east from Eindhoven, was considered.

Recently, the Koninklijke Nederlandsche Heidemaatschappij worked out an engineering plan, concerning the water management of about half of the area under consideration.

The objective of the present short elaboration, is to compare and to consider the coordination between the theoretical concept and the proposed engineering plan.

A very short explanation of the essentials of both reports, mentioned above, is given in order to ensure, that the concepts are well understood and further applied.

1. The theoretical concept

The theoretical investigation had the main objective, to determine the optimal combination of several water management treatments, in order to improve the farmer's annual income per unit area.

The concept involves a method of calculation of the highest possible net increase of the earned income per annum (KOUWE 1964).

The problem is treated in a statistical way, assuming a randomnized position of the combinations of different irrigation and drainage practices. The constraints are formulated:

1.1) $$\sum_{1}^{n} A_i = 1$$

i.e. the sum of the sub areas A_i of each of the treatments is equal to 1, considering the total area as a unity.

1.2) $$\sum_{1}^{n} A_i C_i = C$$

i.e. the sum of the annual costs of each of the treatments multiplied by the corresponding sub area (belonging to the same treatment) determines the mean level of cost (C x 1) for the total area.

1.3) $$\sum_{1}^{n} Y_i A_i - \bar{Y} = B$$

i.e. the mean benefit or net income of the total area, due to the simultaneous application of the different treatments, is equal to the difference between the sum of the mean amounts of earned income from the sub areas multiplied by their partial acreage and the mean level of earned income ($\bar{Y}$) of the whole area under the existing conditions.

1.4) $$B - C = \text{Max.} \quad \text{where} \quad \frac{\Delta B}{\Delta C} = 1$$

i.e. the net benefit B - C is maximum in the point, where the tangent to the resultant curve is parallel to the line B = C.

The laborious work of the calculation can be carried out by means of a digital computer (STOL 1964).

2. The applied theoretical concept

As was mentioned above, the Deurne area served as a pilot plant for the theoretical consideration. Obviously, due to the generalization of the concept and its formulation, the method can be used and applied for other regions or projects, as well.

The Deurne area, as it is concerned here (see map 1 *), is bounded from south by the railway Eindhoven-Venlo, from east by the Peel-Kanaal, from north the Bakelsche Dijk and from west the Oude Aa, covering a bruto area of about 7300 ha, from which, about 20% is occupied by wood, villages and waste land. The rest of the area is used as arable land (55%) and as grassland (45%). (BON 1962).

Some basical studies, works and data were carried out and collected respectively:

2.1. A study on the geological pattern of the area and its influence (due to its numerous faults) on the configuration of the groundwater table (DE RIDDER 1962).

2.2. The fluctuation of the water table, during several months, was recorded and the configuration of the mean winter and summer water table was analyzed, interpreted and constructed (absolute isohypses) (BON 1962), by use of the former mentioned geological concept, as well as, previous data collected and summarized in C.O.L.N. reports (VISSER 1958).

2.3. Based on these hydrological maps, using detailed elevation maps, the maps of the mean water table depth below the surface (relative isohypses) both for winter and summer time, were constructed (BON 1962).

2.4. Further, considering these relative isohypses maps and involving available soil maps and data on crop yield from the C.O.L.N. report, (VISSER 1958), several yield diagrams were constructed (BON 1962), which give the relationship between the yield depression in %, subject to the depth of the water table (winter and summer time), type of soils (profile groups classified hydrologically) and the two existing crop groups (grass land and arable land).

2.5. A field survey, dealing with the yield of several crops in the area under consideration, was carried out (SNIJDERS 1962). Due to this survey, and considering the cropping pattern of the area, as well as the influence of the undulating sandy soils, (KOUWE 1962) a curve was constructed, giving the relationship between the annual income per ha, and the depth of the water table below the soil surface (VISSER and SNIJDERS 1962). This curve was later revised and recently, a new curve was

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*) The various maps, diagrams etc. mentioned below will not appear here. For further contemplation see references.

constructed, involving the flexibility of the farm management system, too (VISSER 1965).

2.6. The scheme of calculation, used for this pilot plant is further considered here, as it was done by KOUWE (1962):

The simplified model used involves several hydrological features of treatment, which affect the moisture condition in the soil during the summer time. Considering the total area as a unity, all the treatments applied, were expressed in percentages according to their acreage:

A_1 - drainage of the wet area
A_3 - area which does not require any treatment
A_4 - subirrigated area
A_6 - sprinkling irrigation from open water courses
A_7 - sprinkling irrigation from deep wells

The mutual effect of the combined treatments on the hydrology of the whole area, considering the direct effect of the specific treatment on the applied part from the area, as well as, the effect of it on the adjacent areas, was analyzed (ERNST 1964). The assumed model used by Ernst for sake of simplicity, consisted of an uniform homogeneous soil profile, with parallel rivers, crossing the whole area with a spacing of 2000 m between them. The area which requires drainage, is supposed to be close to these rivers or brooks. Maximum lowering of the water level in the ditches was assumed to be $dh_{01} = 0.15$ m. The water supply for subirrigation (A_4), as well as for sprinkling (A_6) is provided by means of open water courses (A_5) and for sprinkling (A_7) also from deep wells (A_8). The acreages of (A_5) and (A_8) (the water supply systems) are assumed zero, for any practical purpose, due to their insignificant size.

Assuming boundary and initial conditions and hydrological parameters ERNST solved the problem, in terms of some mathematical formulae for a steady state case by using a relaxation method.

According to the distribution of the partial area, subject to the depth of the water table a straight line relationship was established between the cumulative area plotted on a probability scale and the depth of the water table plotted on a transformed logarithmic scale $\log(x + 20)$ (fig.1).

Consequently the occurrence of the subareas $A_1 \ldots A_7$ from high to low water table respectively is assumed, considering A_1 (drainage) to be at the extreme left part of the curve, (the region of highest water table), followed by A_3(no treatment) further A_4 and A_6 subirrigation and sprinkling irrigation treatments respectively, which can be applied on soils with either higher or lower level of groundwater table and A_7 (sprinkling from deep wells) which is assumed to be practised on the highest spots, with the lowest water table depth.

The first equation established is:

2.6.1. $A_1 + A_3 + A_4 + A_6 + A_7 = 1$

The calculation of the annual income was done by multiplying the earned mean income, taken from the curve developed by VISSER and SNIJDERS (fig. 2) (i.e. the earned annual income against depth of the water table) and the above mentioned distribution curve of the area. This yield curve (fig. 2) shows, that the maximum earned income, for an undulating sandy soil, can be fl 783.- per ha per annum if the depth of the water table is 1.30 m.

Without taking into consideration the unevenness of the land surface, the maximum of fl. 863.- per ha and per annum, can be taken in account if the water table depth is 1.25 m below the soil surface. Assuming that the benefit obtained from sprinkler irrigation is not affected by the unevenness of the area and the depth of the water table, for these treatments a maximum constant annual earned income of fl. 863.- was taken.

Based on these assumptions, a table which gives the cumulative earned income for intervals of 5% acreage, for the existing situation was constructed using the formula:

2.6.2. $I_n = \sum_{1}^{20} Y_n A_p$

where I_n is the cumulative earned income for n intervals ($1 \leq n \leq 20$) of 5% acreage.

Y_n is the mean earned income for one interval subject to the depth of the water table

A_p is the partial acreage equal to 0.05 x A

A is total area taken as a unity.

The same procedure was applied for changes in water table, by lowering (-dh) or increasing (+dh) the height of the water table with 10 till 60 cm every 10 cm. The change in the water table for the various combinations was calculated by Ernst's theory mentioned above.

The mean earned annual income computed for the existing situation is fl. 710.- per ha. The net earned income or the benefit (see 1.3) was calculated by the difference of the sum of the mean earned income from the subareas and the mean earned income on the existing situation upon the whole area.

The costs per annum for different techniques were considered. Assuming a total investment for the different types of treatments per ha: A_1 = fl. 420.-, A_4 = fl. 2450.-, A_6 = fl. 1800.-, and A_7 = fl. 1250.-, the annual cost C_i, became fl. 60.-, fl. 165.-, fl. 190.- and fl. 150.- respectively (considering 5% annuity and the rest operation and maintenance). C_3 was considered zero. So the formula of determination of the mean level of cost became:

2.6.3. $60\ A_1 + 165\ A_4 + 190\ A_6 + 150\ A_7 = C$

for C varying from fl. 0 - 190 in intervals of fl. 5.-

As the constraints imply an infinite number of solutions owing to simplicity for the computation, a certain technique was used (for details KOUWE 1962).

So, the calculations were made for 4 constant levels of acreages of A_1, i.e. 0, 5, 7,5 and 10%. For each level of C_x, the maximum benefit (B_{max}) was extracted. For each of these 4 levels of A_1, a curve of B_{max} as function of the cost C_x was constructed. In order to define the maximum net benefit, max ($B_{max} - C_x$) the $\Delta B_{max}/\Delta C_x = 1$ was found graphically, as well as analitically (see fig.3 - KOUWE 1962).

Interesting conclusions were drawn (KOUWE 1962), partly they are given here:

Considering the peak values (net benefit) of the four curves:

1. The maximum net benefit is varying from fl. 45.- to fl. 50.- between annual costs of fl. 59.- to fl. 68.- and for A_1 varying from 10%-0% (fig. 5). The maximum of the max ($B_{max} - C_x$) is reached when A_1 = 0. (fig. 4).
2. The A_3 (no treatment) is covering quite constantly 56% of the total area.
3. Subirrigation seems to be very unattractive (for the combination of the peak net benefits).
4. About 44 of the area is covered by the other three treatments, mainly by sprinkling irrigation, with an increased percentage of irrigation from deep wells by diminishing the drainage treatment and irrigation from open water courses. For instance for the case $A_1 = 0 - A_6 = 7$ and $A_7 = 37\%$.

Considering only the curve of $A_1 = 5\%$ some other important remarks were given:

1. Concerning the shape of the curve, the net earned income is increasing very rapidly for relatively low costs but after a level of cost of about fl. 25.- there is just a very slight increase. By comparing the maximum net benefit with the net benefit on the level of cost of fl. 25.-, it can be shown (a private remark) that the difference in the net benefits is in the order of magnitude of about 10%, while the difference in the investments are in the order of magnitude of about 200%.
2. By extracting the net benefit of the non-treated area (A_3) only subject to the invested mean annual costs, KOUWE shows in a curve that the maximum net benefit is reached on a level of cost of fl. 15.- per ha per annum. (The resulted combination: $A_1 = 5\%$, $A_4 = 7\%$ and $A_3 = 88\%$).

These conclusions seem to be correct for the other computed curves of different A_1 acreages too (in the range of $0 \leqslant A_1 \leqslant 10\%$).

The main conclusion, as it was pointed out (VISSER 1964), it is, due to possible inaccuracies of the assumptions, advisable in some circumstances to choose a slightly remunerative combination, with a lower initial investment from an economical point of view, especially when the differences in the net benefit seem to be not too high.

3. <u>The water management project submitted by the K.N.H.M.</u>

The project worked out by K.N.H.M. concerns the area bounded by the Kaweische Loop in the north, Peel-kanaal in the east, Vreeswijkse Loop in the south and the Oude Aa in the west.

The basical concept of this plan, as it was explained, in the submitted report, concerns three main problems:

1. Damages to the agriculture during the winter, caused by the high water table. The "trafficability" in the fields is disturbed during the spring, which implies delay in agrotechnical works and consequently a shorter growing period for the plants.
2. Damages to the agriculture during the summer time, caused by drought of water deficiency in the soils.
3. Need of regulation and control of the sewage facilities.

The plan was based on data obtained from:

a. Aerial photos
b. Researches carried out by I.C.W. (BON and DE RIDDER 1962) and C.O.L.N.
c. Soil maps of "Stiboka", Wageningen
d. Soil survey carried out by K.N.H.M.
e. Elevation and topographical maps, supplied by "de Aa" district.

The conclusions drawn, were:

1. The winter groundwater table level in the majority of the area is between 0-70 cm (The minimum required for grassland is assumed to be 40 cm).

   The causes for the high water table and for the swampy areas are:

   The geological features (faults)

   The small capacity of the water courses due to their size to carry away the required discharges
2. There is a water shortage for the plants in summer time caused by the drop of the water table to 70-140 cm and due to the insufficient water holding capacity of the soils. A yield depression of about 10-30% is expected.

The proposed solution:

The main concept involves the control of the primary channels in the area in order to be able to remove the excess water from the agricultural lands in winter time by the small brooks or further by subsurface drainage, if it will be necessary. The outlets of these channels will be to the three main collectors of the area, i.e. de Kaweische Loop, de Vlier and De Oude Aa. These collectors are in a good condition and capable to collect this surplus discharge without any further investments, only the conventional annual maintenance.

As discharge criteria, four run-off coefficients were assumed: 0.33, 0.67, 1.00 and 1.33 l/sec/ha. The total discharge from the whole area will amount about 3-4 m^3/sec.

For the summer time the same channel will serve for water supply, by maintaining a desirable height of water level (by aid of weirs).

Generally it is assumed that the design level of the water in the channels (in summer) has to be 50 cm below the surface, for grassland and 70 cm for arable land. The water requirement is based on 3 mm/day or 0.7 m^3/sec. for an area of about 2000 ha.

The water will be supplied from the south-east corner of the area (from Peel and Deurne channels). About 28 weirs will be necessary, in order to control the summer water levels in the channels.

Available maps concerning the plan are:

Situation map of the whole project 1 : 10,000

Longitudinal sections and cross-sections of the channels in a scale $1 : \frac{100}{1000}$.

The cost of the proposed project has been estimated to be about fl. 3.5 million.

4. <u>The present test</u>

This test concerns the calculation of the benefit, due to the improvements induced by performance as it was proposed on the engineering plan.

The area south from the railway which was included in the engineering plan was cut in order to fit the boundaries of the area with these given by I.C.W. So the borders of the considered plan were (see map 1): south the railway, east the Peel Kanaal, north the Kaweische Loop and west the Oude Aa. This area covers about 3900 ha from which about 900 ha are neither included in the calculation nor in the engineering plan, as this part is belonging to the intravillainial domains, woods or high plots which requires higher investments for their reclamation. This tested part covers somewhat more than half of the area considered by I.C.W.project, as the boundaries of the last mentioned project extended to an area north from the Kaweische Loop, as well.

As it was pointed out above, the proposed plan of K.N.H.M. is based of channels, which are covering the total area by a more or less dense system (100-1000 m).

The tools used in this test were based on the principles of the theoretical concept given above. As the engineering plan of the area is established, the expected hydrological feature of the area is calculated not in a randomnized way.

In order to bring the engineering plan to a common denominator with the plan based in the theoretical concept, the computation of the benefit was based only on the hydrological data of the summer season.

The work carried out under the proposed test was based on the maps used by BON (1962) on a scale of 1 : 25,000. *)

The following steps were done:

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*) In sake of saving the laborious drawing work, only two of the maps are presented here in a reduced scale (1 : 50,000) which may give a sufficient insight about the procedure carried out.

1) The channel system as it was designed by K.N.H.M. was drawn in a situation map in the above mentioned scale.
2) The designed absolute summer water levels in the channels were defined from the longitudinal sections and plotted on the situation map.
3) A new absolute water contour map (absolute isohypses) was constructed based on the height of the water levels in the channels and following the main pattern of the previously prepared absolute isohypses map, which concerns the existing situation (BON 1962). (map 2).
4) The relative water table contour map was reconstructed according to the differences and changes obtained in the pattern of the absolute isohypses map.
5) The acreages of the partial areas subject to the depth of the water table below the soil surface was planimetrated. The data concerning the distribution of the total area, are given below:

Table I.

Depth of water table in cm.	0-20	20-40	40-70	70-100	100-140	140-200	200	total area
The existing situation in ha		3.5	105.5	486.5	1005.0	928.5	510.0	3039.0
The expected situation in ha		52.5	337.0	860.0	1244.0	487.0	58.5	3039.0
The area %								
exist.sit.	0.1	3.5	16.0	33.1	30.5	16.8	100.0	
expect.sit.	1.7	11.1	28.3	40.9	16.1	1.9	100.0	
The cumulative acreage in %								
exist.sit.	0.1	3.6	19.6	52.7	83.2	100.0		
expect.sit.	1.7	12.8	41.1	82.0	98.1	100.0		

The cumulative relative acreages (in %) for the existing situation as well as for the expected one, were plotted on a probability paper. For the abscissa the mean water table depth of the intervals was taken in the transformed logarithmic scale - log (x + 20) . As result, two straight lines were considered (one for each situation). (see fig. 5).

The mean earned income for the total area (taken as a unit) was calculated from the sommation $\sum_{n=1}^{20} Y_{n}/20$ as the partial acreage was taken for intervals of each 5% and Y_n was calculated from the yield curves, considering for every acreage interval a mean depth of the water table.

In sake of meditation and comparison the calculation was done for three yield curves (fig. 2) which have the same peak value (fl. 783.-) (VISSER & SNIJDERS). According to the theory (VISSER 1965) every curve expresses different conditions and circumstances: curve 2 concerning the yield on an undulating sandy soil, curve 3 the earned income by involving in addition the labour income and curve 4 gives the earned income, while the flexibility of the farm is considered, as well. The curves 2, 4 and 3 have their peak value at a depth of water table of 92 cm, 113 cm and 130 cm respectively.

Table II.

Computation of annual earned income in fl. per unit area

		depth of W.T. in cm.		Y_n(Graph 2)		Y_n(Graph 4)		Y_n(Graph 3)	
n	acreage A_p %	exp.	exist.	exp.	exist.	exp.	exist.	exp.	exist.
1	0- 5	51	65	640	717	604	688	598	668
2	5- 10	63	81	708	772	670	735	660	724
3	10- 15	70	90	736	782	698	758	688	741
4	15- 20	77	100	762	782	723	775	712	763
5	20- 25	81	105	772	779	735	780	724	770
6	25- 30	85	112	778	771	746	783	735	777
7	30- 35	90	119	782	760	758	781	747	780
8	35- 40	94	125	783	748	766	777	754	782
9	40- 45	97	130	782	737	771	772	759	783
10	45- 50	102	135	781	725	777	765	766	782
11	50- 55	106	142	778	709	781	754	771	780
12	55- 60	110	150	776	688	782	738	775	774
13	60- 65	115	158	767	665	782	718	778	764
14	65- 70	120	165	758	650	781	702	781	754
15	70- 75	126	172	747	630	776	683	782	740
16	75- 80	134	183	728	598	766	650	782	716
17	80- 85	140	193	713	570	757	616	780	688
18	85- 90	150	210	688	527	738	569	774	628
19	90- 95	165	230	655	484	702	518	754	564
20	95-100	195	278	565	420	612	433	681	453
ΣY_n				14.694	13.514	14.725	13.985	14.801	14.437
$\bar{Y} = \Sigma^{Y_n}/_{20}$				735	676	736	699	740	722
$B = \bar{Y}_{exp} - \bar{Y}_{exist}$				59		37		18	

As the estimated investment for this 3000 ha is about fl. 3 million, i.e. fl.1000/ha, assuming an annuity of 5% and an annual maintenance of fl. 20, the cost C per ha per annum will be about fl. 70.

In this case the benefit-cost ratio B/C will be 0.85, 0.55 and 0.25 respectively for the three considered curves. The difference B-C will be in negative magnitude of -fl. 11, -fl. 33, -fl. 52 respectively.

Discussion

It has to be accentuated that the concepts which governed these two approaches are different.

The engineering plan considers very high damages in the winter time and even in summer time a yield depression of 10-30%. So, the plan is based on a du-purposed channel system, which has its main objective to lower the water table during the winter time and to keep a relatively high water table in the channels during the summer time. The sprinkling irrigation is not proposed at all, due to its requirement for high investments.

Considering the results of the test and comparing them with the results obtained in the applied theoretical approach, it may be remarked:

The area considered in this test is relatively more wet even in summer time, than the total area considered in the I.C.W. elaboration. For example, by comparing the distribution curves of the partial and total area, as given in this test and by KOUWE (1962) (see fig. 5), for a relative acreage of 50%, the depth of the water table is 138 cm and 150 cm respectively. Consequently, due to this shift of the distribution curve, the earned mean income for the existing situation is considered in the test higher (fl. 722) than in KOUWE's computation (fl. 710), both values calculated from graph 3.

Due to this yield curve, the above mentioned existing situation is considered highly productive with less than 10% yield depression on the average. The maximum $\left[(783-722) < 70\right]$ benefit cannot cover even the annual cost, as the expected situation reached through the proposed treatments in the engineering plan may imply a maximum earned income of fl. 783 instead of fl. 863 income assumed for improvements obtained by irrigation practices. In the applied theoretical concept, the drainage problem was assumed as a marginal one, and as it was shown the maximum net benefit is obtained when neither drainage facilities nor subirrigation are used.

Trying to analyze the conclusions reached in the applied theoretical approach (KOUWE & VISSER 1965) it may be further remarked:

1. The trend for no use of drainage

This treatment is influenced by its relatively high annual cost, comparing with the possible remunerativeness due to its low effect on the yield. As an example, computing for an unit area with a water table depth of 85 cm for the existing situation, due to the drainage facilities the water level will drop with maximum 15 cm (see assumptions) i.e. the new situation will be 100 cm. As the annual cost for drainage facilities assumed by KOUWE is fl. 60 per unit area, the surplus income (see graph 3) is fl. 763 - fl. 735 = fl. 28, so the net benefit will be - fl. 32.

The depth of water table which can justify drainage, just for a benefit-cost ratio of 1 (i.e. net benefit = 0), is 60 cm, for the initial or existing situation. The example shows that drainage can be attractive only where high water tables occur. Due to fig. 1 (KOUWE 1962) for h = 60 cm the acreage is less than 1%, so drainage facilities covering an area of more than 1% are causing a deficit (according to the assumptions).

2. The trend for no use of subirrigation

The subirrigation involves an annual investment of fl. 165 per ha, while the direct effect on the yield can be not more than fl. 783 - fl. 710 = fl. 73 per ha. Thanks to its influence on the adjacant areas, where no treatments are practised and by increasing their recompensation, the subirrigation can be justified, but only for a combination of relatively low costs and consequently for small areas. Subirrigation seems to be more attractive in combination with drainage facilities.

3. The trend for sprinkling irrigation

The first insight is showing, that even the increased income per ha (fl. 863) differs from the mean just with fl. 153, while the cost per annum per ha for sprinkling is, from open courses fl. 190 and from deep wells fl. 150.

However, the factors which are causing to consider the sprinkling attractive, instead of other practices, for high investments, are:

a. Sprinkling irrigation is assumed to cause neither a local rise in the height of the water table nor in the surrounding. In exceptional cases indirect effect can occur, due to the water supply by open water courses. From other side, by extruding water from deep wells a certain lowering of the water table in the wet area is considered too.

b. Sprinkling irrigation is assumed to be practised especially in the high lands, for which the income is below the mean earned income for a considerable high percentage of the area.

Further meditation, concerning the engineering project is difficult to propose.

As the engineering plan has no alternatives, one single value or point will be obtained, when the annual cost against net benefit is plotted (similar to the graph presented in fig. 3a).

In sake of further speculation, there may be assumed, for instance, three more alternatives with annual level of costs of fl.17.5, fl. 35 and fl. 52.5 which constitute 25%, 50 % and 75% of the total annual cost (fl. 70) respectively. These less extended alternatives, will cause to a change of the water table configuration in a different way, from this caused by the submitted engineering project. The assumption proposed and applied here, concerning the change in the water table, has any theoretical justification or base. It simply considers three straight lines, situated in between the existed and expected distribution lines of the area with a relative distance, divided between them, of 25%, 50 % and 75% respectively from right to left (see fig. 5).

The computation of the income for these curves was carried out in the same way as described previously for the 100% level of annual cost, but only for curve 2. Without ignoring the peculiar meaning and the special circumstances which may allow the application of any proposed yield curve, curve 2 was applied here, because of giving the highest differences in income values for the circumstances which exist and which are expected, as a result of carrying out the engineering project.

Table III below, gives the final results and comparison between them:

Table III

	Existing $\bar{Y}_n$ (C=0)	Expecting Y_n C= 100%	75%	50%	25%
Mean annual earned income fl. per ha	676	735	724	710	694
B = $\bar{Y}_n$ exp. - $\bar{Y}_n$ exist.		59	48	34	18
Mean annual cost fl. per ha		70	52.5	35	17.5
B - C		-11	-4.5	- 1	+ 0.5
B/C		0.84	0.92	0.97	1.03

An other theoretical possibility is to reach the maximum earned income per ha, i.e. fl. 783 which gives a net benefit of fl. 107. It is difficult to estimate the level of cost which will result to this maximum income.

Figure 6 shows the results graphically, as well.

Conclusions

Using the theoretical concept the engineering plan proves to be doubtfully justified from economical point of view.

The assumptions which govern the theoretical approach may be correct and justified objectively for certain circumstances and conditions. It appears to be less correct when the dominating criterion is the drainage problem during the winter time and the water management of the summer time is supposed to be a side problem, as the engineering project's concept assumes. For such circumstances it may be supposed that an other scheme of computation has to be considered and applied and consequently the results may differ from those obtained in this test.

As it was already accentuated, due to the productivity of these soils, for the existing and practised crop pattern, the shape of the yield curve is the main factor which affects the results, taking in consideration the existing relatively high mean earned income over the total area.

It is difficult to justify economically such a project, which from one side requires relatively high investments and from the second side assumes a quite high productivity of the land in the existing situation, without possibilities to increase it considerably for the prevailing agricultural conditions.

Further contemplation is beyond the scope of this test, it is worthwhile just to accentuate, as it was pointed out (VISSER 1964) that the final decision, concerning reclamation of an area, and its water management can be governed some time by other "national, economical and social considerations".

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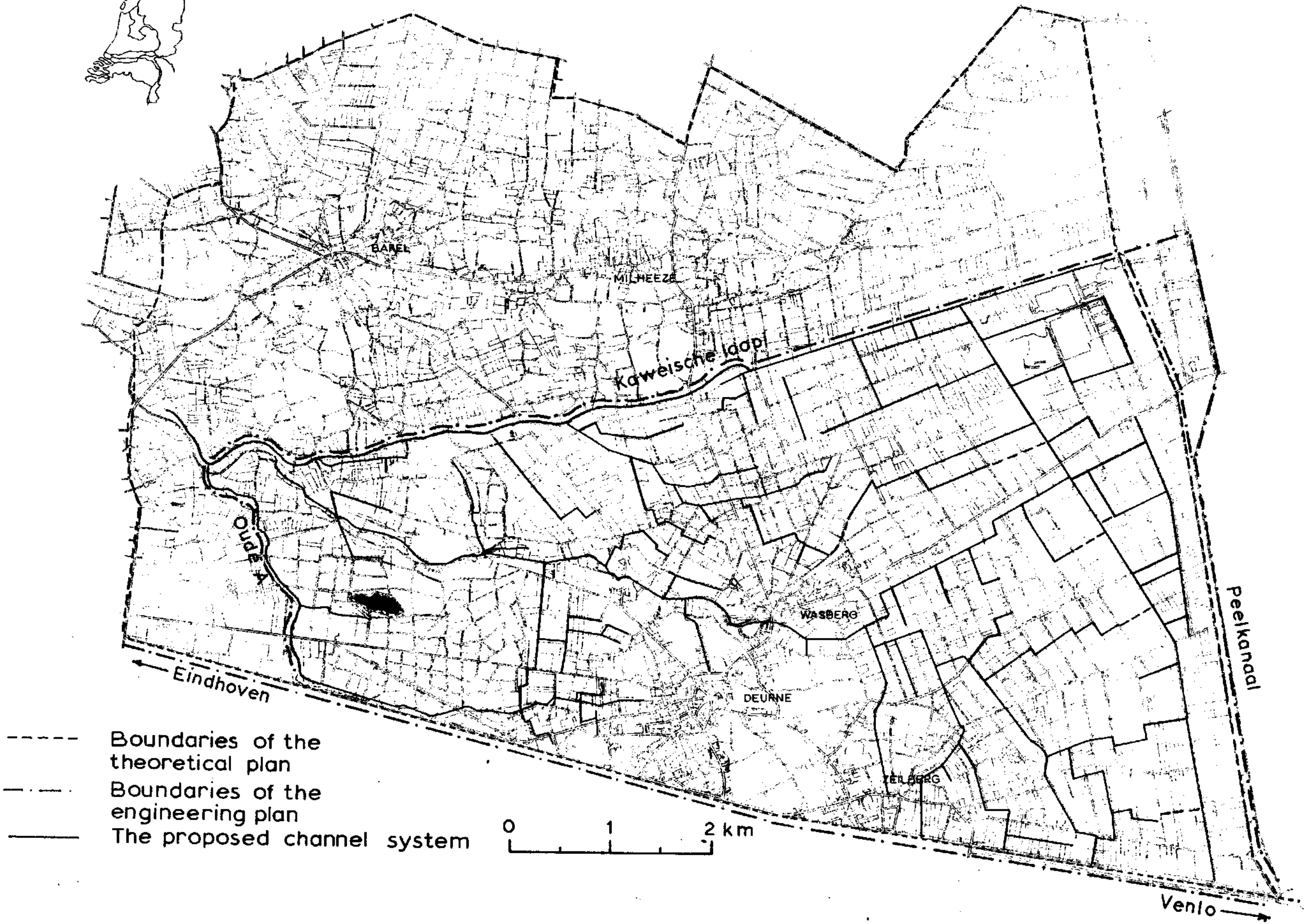
* All the papers mentioned, except the last one, are not yet published.

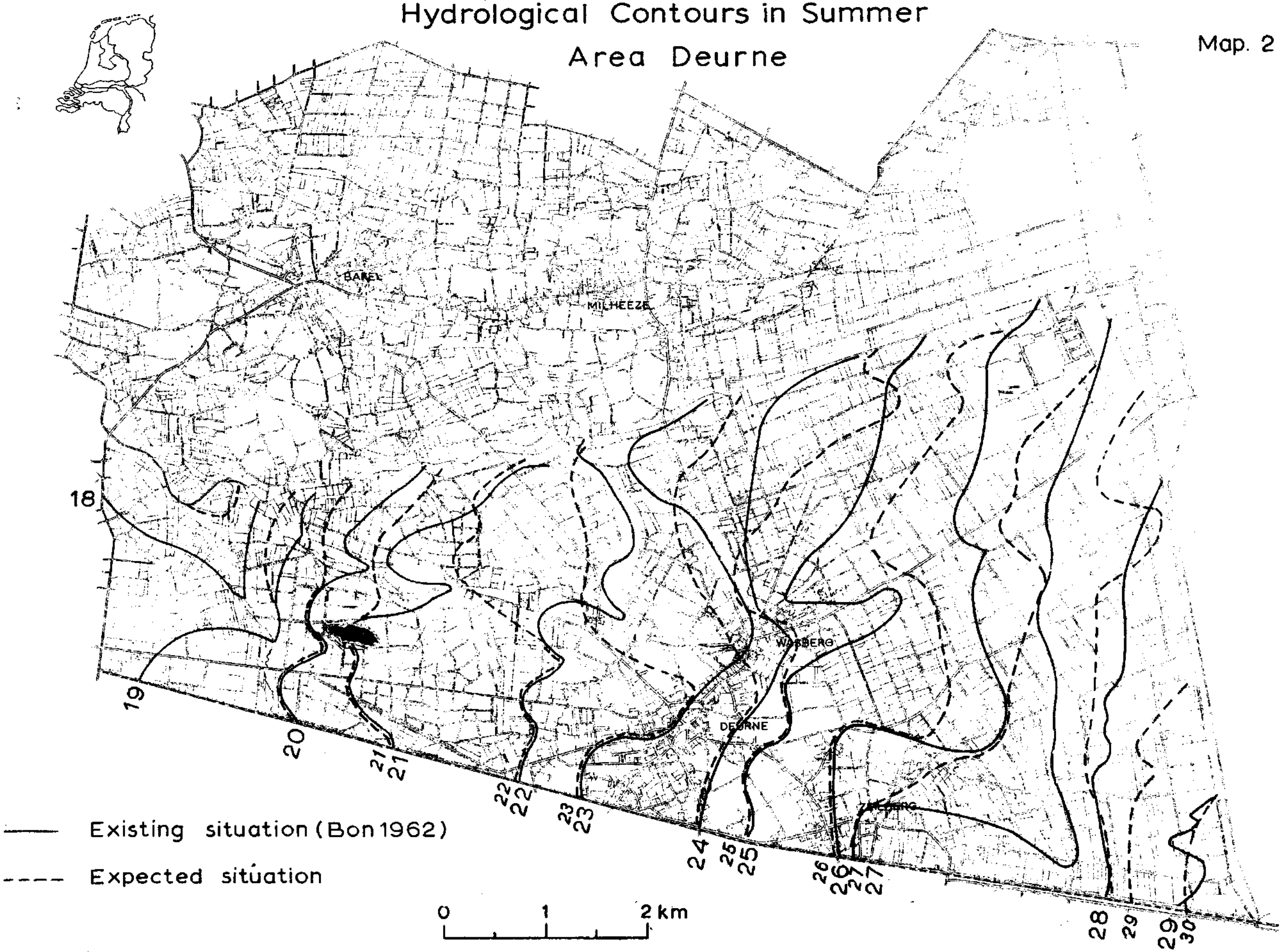
Deurne Area

Map. 1



Map. 2

Hydrological Contours in Summer
Area Deurne

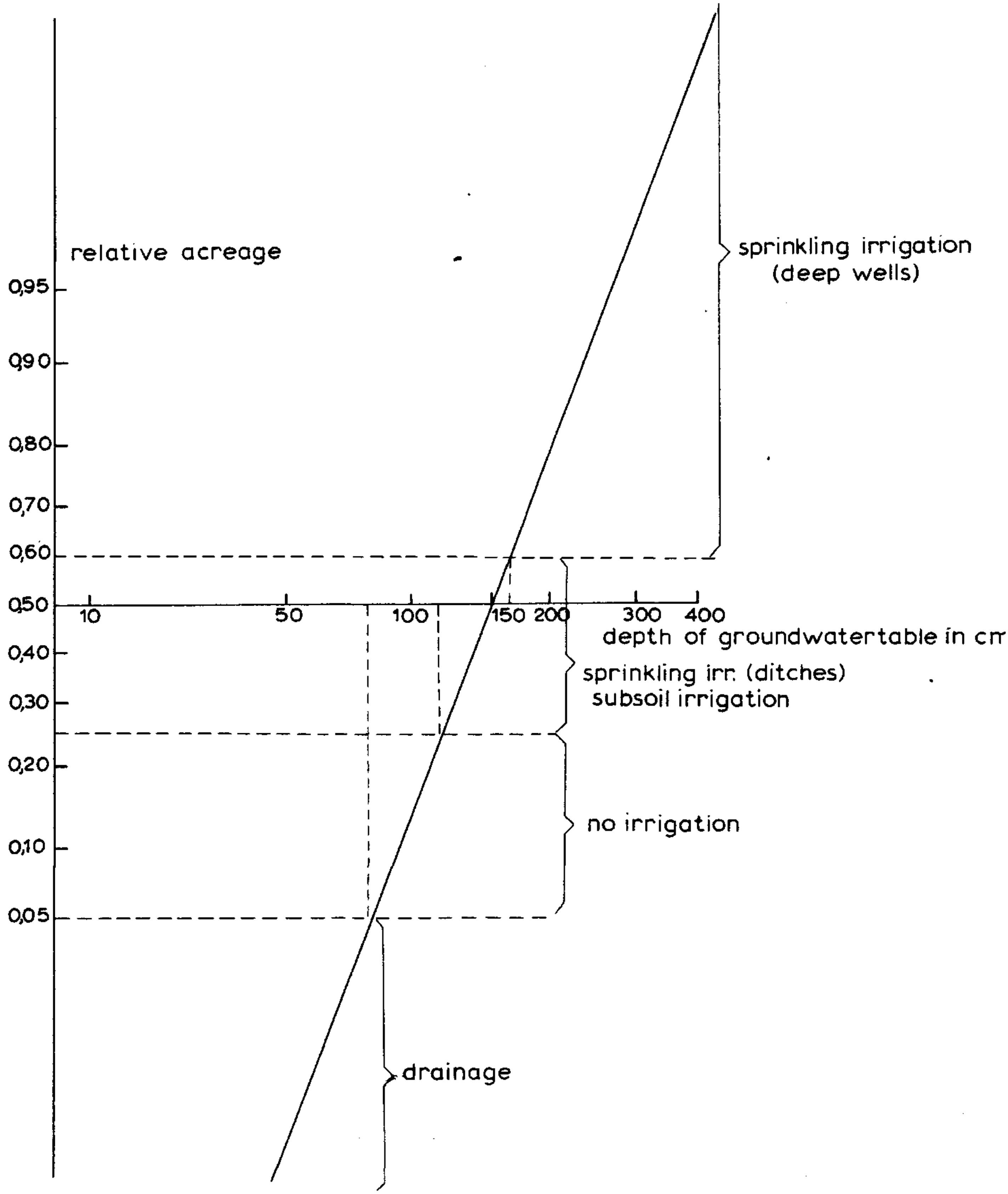


—— Existing situation (Bon 1962)

- - - - Expected situation

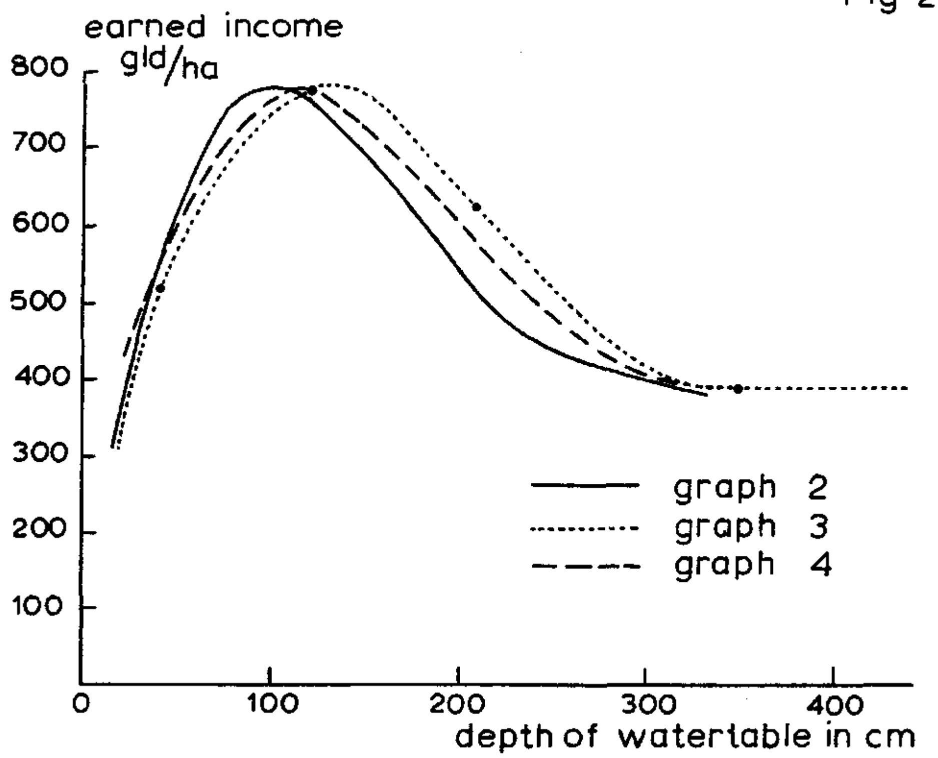
Fig. 1

Distribution of the areas with different irrigation methods on the probability curve for the depth of watertable for the best area near Deurne



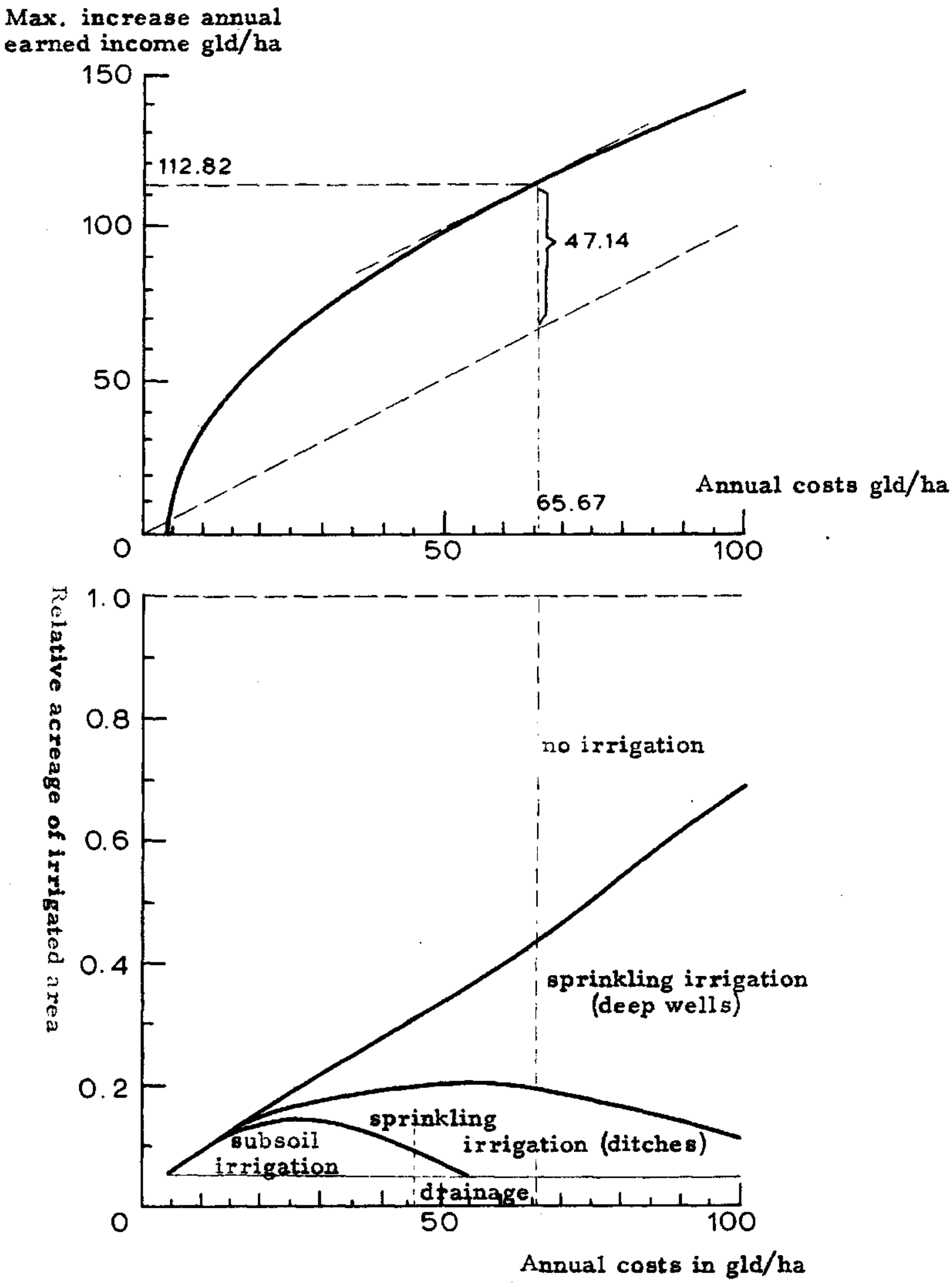
After Kouwe 1962

Fig 2



The relation between earned income and depth of watertable according to several basical assumptious
(Visser en Snijders 1964)

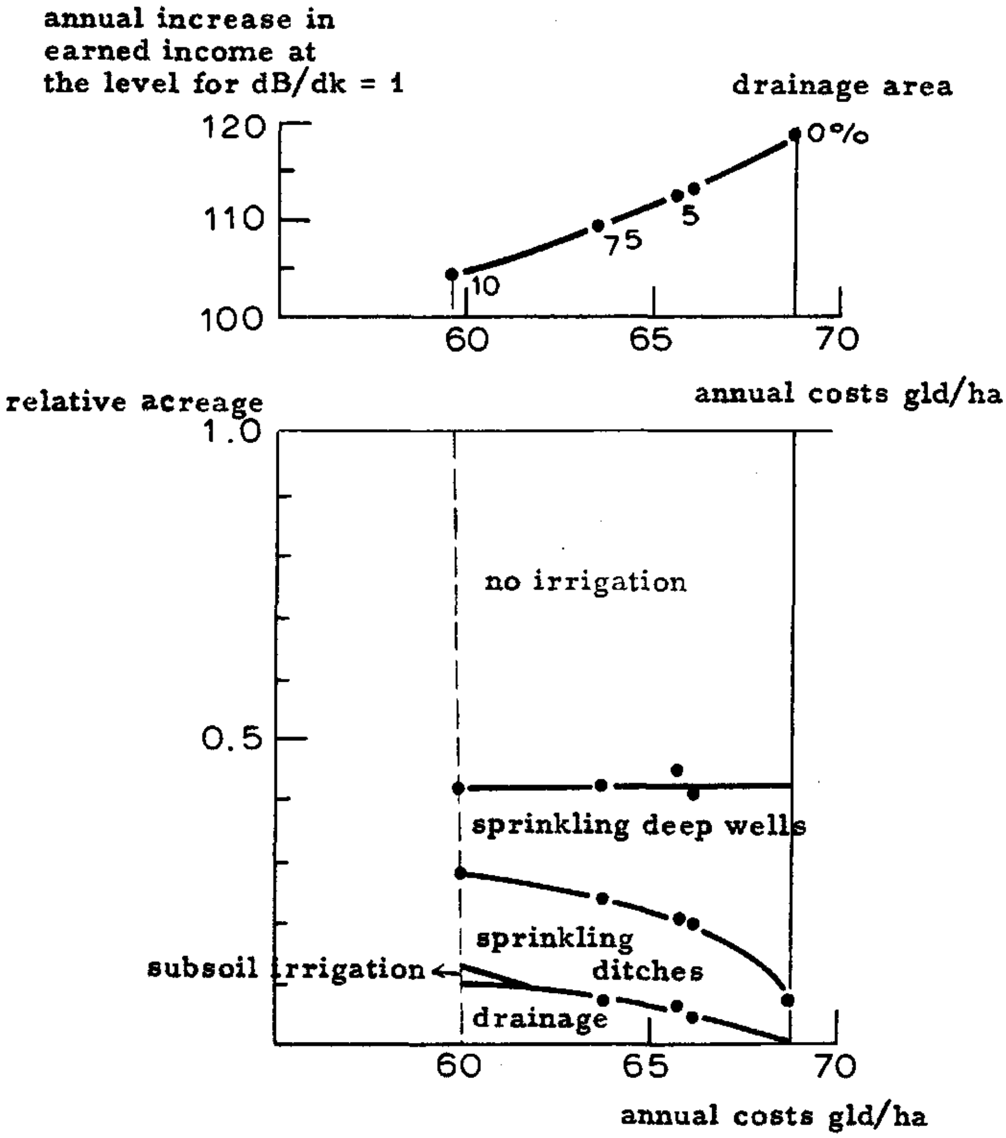
Fig. 3



65 C 14.1/2.1

After Kouwe & Visser

Fig.4



65C 14.2/2.1

After Kouwe & Visser

Distribution curve of the area subject to the depth of the water table

fig. 5