INSTITUUT VOOR CULTUURTECHNIEK EN WATERHUISHOUDING
Nota no. 110 dd. 29 november 1961

WATER MANAGEMENT AND CROPPING PATTERN

The influence of hydrological farming conditions upon the cropping pattern of the undulating sandy soils around the flat delta area

J.H. Snijders

INTRODUCTION

In order to obtain effective knowledge of the economical significance of water management in farming, many-sided research has to be done. The effect of measures such as drainage of soils being generally too wet or irrigation of drought sensitive and desiccating soils, will not merely be a matter of increasing production. It rather is the opportunity, afforded by hydrological improvements, to revise an inexpedient production scheme, that will prove to be of prime importance. The bigger the deviation from the original humidity condition of the cultivated land, the more radical this reconsideration generally will have to be to obtain optimal results. Modifications within the cropping pattern may be considered the base of the adaptation of farms to changing hydrological farming conditions. A totally different proportion of pasture to arable land may come into existence, growing frequencies of arable crops may alter considerably, some crops will have to abandon the field, other will be introduced. Alteration in long existing crop rotation systems, that are often of traditional latency will mark these developments.

Both increase of crop yield as well as modifications in the cropping pattern are obvious results of adequate water management in originally dry regions. Whereas increase of crop yield, however, represents that part of computing the net-revenue of farming, which in the past may have been studied most, cropping pattern analysis is much less known although it definitely can't be neglected since water management research comprises farming in its entirely. Actually, to be able to predict with some accuracy the profits of hydrological improvements any part of farming has to be taken into consideration. So, next to crop yields and crop frequencies, other important aspects of farming such as labour requirement, fertilization habits and cattle stock in particular, will have to be studied.

268/1161/10

Yield depression curves regarding varying groundwater levels of sandy soils have been available for some time, whereas research on the influence of soil humidity conditions upon the labour requirement of potato growing on sandy soils did already procure some understanding about to which extent labour will increase in case dry sandy soils will be irrigated[1]. Results of research on fertilization habits and livestock farming under varying hydrological farming conditions, will be discussed in a seperate paper, logically joining the present one in which particularly the influence of water management upon the cropping pattern has been analysed.

Recapitulation of the results of these rather divergent surveys has been performed by way of drafting a number of analogical farming budgets, in which costs and revenues of farms being in successive stages of water management, have been based on present hydrological knowledge. With that the last paper represents a natural conclusion of this series.

DATA

Data have been sampled by way of a rather wide investigation, comprising 72 farms with a total of about 1100 clearly separate fields, that has been executed in close co-operation with assistents of the Governments Agricultural Extension Service in eastern North Brabant at Eindhoven.

In table 1 the topographical distribution of these farms has been given.

[1] Snijders, J.H. Vochttoestand van de grond en arbeidsbehoefte: I.C.W.-rapport no.5, 1958.

Table 1

Topography of farms investigated in eastern North Brabant

Areas	number of farms	number of fields
Municipality		
1. Asten and Ommel	5	62
2. Middel-, Oostel- and Westelbeers	5	40
3. Hoogeloon and Casteren	5	92
4. Waalre, Veldhoven, Aalst and Oerle	7	144
5. Beek en Donk, Aarle-Rixtel and Stipthout	5	77
6. Gemert and Mortel	5	63
7. Liessel and Neerkant	5	55
8. Deurne	14	156
9. Bakel and Milheeze	6	108
10. Soerendonk and Maarheeze	4	52
11. Bergeijk	5	92
12. Valkenswaard and Borkel and Schaft	6	140
Total	72	1081

Actually the number of fields will be larger, since in practice any field on which, within the period of research, for a couple of years at least, several crops have been grown simultaneously, has been considered to break up into a conformable number of seperate fields. This being taken into consideration, a number of 928 arable fields and 231 grassland parcels have been distinguished, seeded pastures under 4 years being considered arable land. Fields of grassland concern permanent pastures which have been exploited as these for at least 4 years in succession. The total acreage of cultivated land being involved, amounts to a round 830 hectare.

Data concerning the cropping pattern have been collected by recording which crops, for a period of 5 years, have been grown on the 1159 separate fields. Thus a total amount of round 5800 data of crop growing came at our disposal, which is quite sufficient in cropping pattern analysis in case the influence of only one independently varying magnitude upon the frequency in which the various crops are grown, will be derived.

As has been proved in former research, about 10.000 data will be needed in case the influence of a couple of interdependent magnitudes has to be analyzed[2].

With regard to data concerning humidity conditions of the soil, a classification has been made use of, analogous to the one of the soil humidity map, which has been published by the Committee on Agro-hydrological Research in 1958[3], without, however, being actually adopted. In fact, with the investigation, the farmers opinion about the mean humidity condition of each seperate field has been asked on the basis of this very classification. In behalf of cropping pattern analysis this kind of practical judgment is of particular significance. A number of five hydrological stages has been distinguished: frequently desiccating soils (F.D.), drought sensitive soils (D.S.), soils of a good water retaining capacity (G.C.) soils which will be flooded occasionally (O.F.) and soils being alternating too dry or too wet (D.W.). To obtain continuity, however, this last class has not been taken into account in analysing crop frequencies, whereas another stage, the one of soils being generally rather too wet (T.W.), has been projected between those of hydrologically prime soils and extremely wet soils.

Data concerning mean groundwater levels have been taken from groundwater level maps, also being composed by the Committee already mentioned above. A number of seven classes has been distinguished i.e. 0-20, 20-40, 40-70, 70-100, 100-140, 140-200 and over 200 cm.below soil surface respectively.

2) Visser, W.C. and J.H. Snijders. De geschiktheid van de profielen in het Geestmerambacht voor de tuinbouw, gemeten aan bouwplan en arbeidsbehoefte. I.C.W.-rapport no. 9, 1960.

3) Committee on Agro-hydrological Research in the Netherlands (COLN-TNO) Report I-XII, Staatsdrukkerij, 's-Gravenhage, 1958.

THE CROPPING PATTERN OF THE UNDULATING SANDY SOILS AROUND THE DELTA PROPER.

In order to give an impression of crop ratios, ruling in this area for the last 5 or 6 years, in table 2 percentages have been given, in which each seperate crop is represented in the cropping pattern. Crops have been ranged here after their frequency of occurrence. In fact these figures render the average cropping pattern of the 72 farms that have been investigated.

Table 2

Cropping pattern of eastern North Brabant as derived from data of 72 scattered farms

crops	frequency in per cent (F%)
permanent pastures	24.3
rye	24.0
seeded grassland	10.9
oats	10.8
oats-barley mixed crop	10.1
potatoes (consumption)	9.0
fodder beets	4.5
corn	1.8
barley	1.0
extensive horticulture,asparagus,herbs	0.9
peas	0.8
sugar beets	0.7
red clover,alfafa and serradella	0.5
wheat	0.3
miscellaneous fodder crops (spurry, forage rye)	0.2
lupine	0.2
Total	100.0

The cropping pattern is especially marked by the proportion of pasture to arable land which is 1:3, seeded grassland being reckoned among arable land. In case seeded grassland is taken together with permanent pastures, the proportion will be 1:2. Of the true arable crops rye is by far the most common. The proportion of cereals to root crops amounts to 3:1.

These three simple ratios may be considered characteristic of mixed farming under natural hydrological conditions on the generally deeply drained sandy soils of the south-eastern part of the country.

Certain crops will be followed by a second one within the same year. In 11.6% of all growings registered during the period of survey, a second crop has been grown, of which no less than 11.3% appears to be for account of rye growing. For it has already been shown, rye participates in the cropping pattern with a mean 24% whereas for 47% of rye growing this crop will be followed by a second one. This proves to be mainly turnips (89%) some clover (6%) or miscellaneous crops such as lupine, spurry and other fodder crops of minor importance (5%).

HUMIDITY CONDITION AND GROUNDWATER LEVELS

The average cropping pattern, being a reflection of the customary scheme of production is strongly dependent on the economical and pedological properties of the milieu. Specialized cropping pattern analysis is not intended to procure a mere representation of the average cropping pattern. It is actually meant to measure the influence upon the cropping pattern, of certain factors, that serve the purpose of being studied.

Hydrological farming conditions have been described by way of mean groundwater levels as well as soil humidity classes. Since this classification is of empirical character it will be particularly interesting to investigate to which extent the farmer in making up his opinion about the mean humidity condition of the soil, let himself be influenced by phenomena caused by local groundwater depths and groundwater fluctuations. At the same time an insight may be obtained into the possibilities of regauging the soil humidity scale into a scale of groundwater levels and conversely.

For this purpose within a limited area near Deurne a stock-taking of humidity conditions has been done. A number of 20 out of the total of 72 farms that have been investigated are situated in the experimental area. A number of 260 fields are involved.

In table 3 a survey of the humidity distribution in this area has been presented.

Table 3

Frequency of occurrence of humidity conditions within the experimental area of Deurne

Humidity classes	F.D	D.S	G.C	T.W	O.F	D.W
Percentages of occurrence	0.5	33.5	50.0	7.0	3.5	5.5

Soils of good water retaining capacity and drought sensitive soils are strongly dominating. Half of the total number of fields has been considered of good water retaining capacity, of the other half 68% is marked by the farmer as being drought sensitive.

In plotting humidity conditions against depths of the groundwater table, one may not expect an explicit relation will emerge, since the humidity condition of the topsoil will be strongly dependent on the water retaining capacity of the profile.

In order to know the function of the groundwater depth in the opinion about soil humidity being accomplished, the percentages of fields of a certain humidity falling within each separate class of groundwater depth, has been computed. Regarding fields of good water retaining capacity results were obtained with respect to groundwater depths in summer as well as in winter; with drought sensitive and wet fields however, results were limited to observations in summer respectively winter only. They have been summarized in table 4.

Table 4

Frequency of occurrence of distinct humidity conditions with various depths of the groundwater table

	Percentages of the total number of fields involved			
Humidity conditions :	Dry (D.S)	Good (G.C)		Wet (T.W)
Groundwater levels cm b.s.s	summer	summer	winter	summer
> 200	46	17	4½	-
140 - 200	22	37	6	-
100 - 140	28	29	14	-
70 - 100	2½	14	15	1
40 - 70	1½	3	31½	17
20 - 40	-	-	27	55
0 - 20	-	-	2	17

With figures 1,2 and 3 a picture of this course of frequencies has been given. The various humidity conditions are found along a wide stretch of variation in groundwater depth. The fields of good water retaining capacity are found most frequently with a mean groundwater level of about 150 cm.below soil surface in summer and of about 50 cm.in winter. Dry fields, principally being drought sensitive, since frequently desiccating fields practically don't occur within the experimental area, will reach their highest frequency with a mean groundwater level in summer of 250 cm. below soil surface or more. Compared to this, the groundwater depth in winter will be of little or no influence. Regarding their frequency of occurrence, wet fields will reach an optimum with a mean groundwater level in winter of about 30 cm.below soil surface, the groundwater level in summer being here of particularly small interest.

Considering in which way the farmer will come to his opinion about the soil being too wet or too dry, the conclusion has to be, this empirical judgment is based on the humidity condition of the soil during crop growth in combination with the soil humidity in moments in which preperatory activities- principally tillage- as well as harvesting- being the natural conclusion of the growing season- will be performed. So the groundwater level in winter will possibly influence the practical opinion about soil humidity in case the necessity arises of moving up ploughing and sowing data on account of a moisture excess in early spring. By this, the impression is obtained of the field being generally too wet or even being "occasionally" flooded. The stretch of mean groundwater depths, being significant for these two "wet" stages of soil humidity, is relatively short. In summer, however, the waterretaining capacity of the soil will outclass the groundwater depth to this respect. This is the reason, why in particular experiences which have been acquired during the growing season as well as with harvesting, will ascertain the qualifications of soils being of good water retaining capacity, respectively being drought sensitive or even desiccating.

Within the experimental area of Deurne, 83% of the fields that have been surveyed, are marked by a mean groundwater depth in summer of over 100 cm.below soil surface. The distribution amounts to: 29% : 100-140 cm b.s.s., 29% : 140-200 cm.b.s.s. and 25% : over 200 cm b.s.s.

The deep groundwater level in summer, being characteristic for the whole area, makes a certain moving up in the scale of humidity conditions into the opposite direction acceptable. Through this, the chances are that desiccation will show insufficiently here. The fact, no frequently desiccating fields have been mentioned, although in a larger scale this stage will actually prove to exist, may be considered another indication. The probability of such shiftings however, meaning but a small limitation of the objectivity in judging yet, is in no way detrimental to the correctness of the hydrological interdependency shown above.

THE INFLUENCE OF WATER MANAGEMENT UPON THE CROPPING PATTERN.

Research on the influence of the milieu in general, upon the cropping pattern will be considerably hampered by the fact, this dependently varying factor is of complicated nature, for it is characterized by means of the mutual proportion of the integral crops. With former research the crop frequency technique, designed by Visser in order to meet this complication, has already proved to be extremely useful. A description of the procedure according to this technique has been given as appendix I. A justification of the bases will be found in the I.C.W.-report, which has already been refered to in this paper as no. 2.

The influence of the humidity condition of the soil

From the data of the inquiry has been derived how many times within the period of survey the various crops have been grown on fields of a certain humidity. In table 5A these frequencies of occurrence have been expressed in per cent of the total number of observations, whereat in order to simplify things crops of little frequency have been added to strongly related crops that are well represented in the cropping pattern.

Table 5A

Influence of the soil humidity upon the cropping pattern

Humidity conditions	Computed crop frequencies in per cent FD	DS	GC	TW	OF
Crops:					
permanent pastures	-	5.8	33.8	61.3	75.2
seeded grassland	-	6.9	14.8	12.3	8.6
rye	48.4	36.7	15.8	5.8	3.2
potatoes	7.2	10.8	8.8	2.9	2.7
oats-barley mixed crop	19.2	16.1	8.4	4.9	1.1
oats	17.2	15.9	7.1	4.8	5.8
fodder beets	0.4	2.0	8.1	6.4	3.4
corn	3.2	3.0	1.0	0.7	-
peas	1.2	1.3	0.5	-	-
miscellaneous	3.2	1.5	1.7	0.9	-
Total	100.0	100.0	100.0	100.0	100.0

For each crop, these frequencies, being expressed in a logarithmic scale, have been plotted against humdidity. The curve, which by reason of the frequency distribution may be drawn for each separate crops is, with this technique, supposed to represent a section of the joint cropping curve of parabolic shape.

In figure 4 for all crops the position of the computed frequency percentages have been represented with respect to the cropping parabola. By way of redrawing the horizontal axes from the original logarithmical frequency figures, an impression will be obtained of the horizontal as well as vertical shiftings, being performed in order to join the separate cropping sections.

Now by reading back crop frequencies from the parabola by means of a logarithmic scale, which has to be placed vertically for this, and plotting these frequencies in a metric scale against humidity, specific probability distribution curves emerge, such as have been represented in figure 5. In fact only the outlined part, comprising the actual stretch of humidity conditions will be of practical interest. In order to show the whole course of the probability distribution however, the horizontal axis has been continued into the direction of wet as well as dry soil conditions. To both sides the total frequency is continuously decreasing to draw near to zero in the end. It will be understood, extreme hydrological situations like these may only concern drift-sand areas in which agriculture will be definitely impossible the soil moisture content being extremely low, or frequently flooded regions, like land on the outside of the dikes for instance, which have not been used as outside pastures yet.

Crop frequencies being converted to the parabola are presented in table 5B.

Table 5B

Influence of the soil humidity upon the cropping pattern

	Crop frequencies converted to the parabola, in per cent				
Humidity conditions:	FD	DS	GC	TW	OF
Crops:					
permanent pastures	1.2	9.0	31.0	62.0	75.0
seeded grassland	3.0	8.2	13.4	13.4	7.9
rye	47.8	36.0	16.9	4.8	0.9
potatoes	7.7	10.8	8.8	4.3	1.3
oats-barley m.c.	17.8	16.9	9.7	3.5	0.7^{5}
oats	16.8	15.6	8.4	3.1	0.7
fodder beets	1.1	3.4	6.5	6.9	4.4
corn	3.3	2.7	1.3	0.4	-
peas	1.3	1.1	0.5	0.2	-
miscellaneous	3.0	2.4	1.2	0.4	0.0^{5}

The relation between the empirically established humidity condition of the soil and the frequency in which the various crops are grown shows very clearly here. Contrary to the experience with analogical research in the province of Overijssel, permanent pastures appear to react in such a clear way, that a separated operation is definitely not necessary here.

With occasionally flooded soils correction of crop frequencies by way of the occurrence of grassland and rye proved to be desirable.

The number of OF. fields being relatively small, the frequency of rye growing and grassland exploitation on these extremely wet soils, has been established by way of extrapolation of the curve which has been found for the stretch from F.D up to T.W fields.

The fact that cereals such as rye and corn are most frequently grown on desiccating soils, whereas permanent pastures are the feature of extremely wet soils, certainly does not mean these crops will show their optimal growth here. It does mean, however, on these hardly paying soils no other crop out of the usual assortment can be expected to do better. With respect to the optimal growth, the other crops are lying in between.

Regarding their reaction to variations in soil humidity, oats and mixed crop show a distinct similarity, mixed crop being all along in the majority however.

The dominating position of pastures in the humid regions makes it particularly clear that, contrary again to Overijssel, improvement of the water management of the dry undulating border land of the delta may lead to a strong increase of the grassland area. The extent to which this phenomenon will be coupled with an increase of the cattle stock has been discussed in a separate paper. It may be important however to point out even now the fact that decrease of arable land as a result of the increasing acreage of grassland, will cause an intensification of arable farming. Along the hydrological stretch from very dry up to clearly favourable soil conditions the growing of cereals appears to decrease considerably, whereas root crops, fodder beets in particular, will show a distinct increase. The course of the curve for potato growing shows that under hydrologically prime soil conditions this crop comprises about 10 per cent of the whole cropping pattern. The so called three-course system regarding the occurrence of patato root eelworm, which, irrespective of the humidity condition, leads to a frequency of potato growing of a little over 30% on almost any arable field on the sandy soils of the northern provinces of Drenthe and Overijssel does not influence crop frequencies in the southern part of the country.

The intensification of arable farming on the decreasing acreage of arable land is also evident from the course of the frequency of growing a second crop. In table 6 this frequency has been expressed in per cent of rye growing.

Table 6

Influence of the humidity condition of the soil upon the frequency of stubble crops after rye growing

	Frequency of occurrence after rye in per cent				
Humidity conditions	FD	DS	GC	TW	OF
Crops:					
stubble turnips	17.4	41.8	47.1	57.7	52.6
clovers	-	1.8	3.7	3.8	5.3
miscellaneous	3.3	3.2	2.3	-	-
Total	20.7	46.8	53.1	61.5	57.9

In figure 6 this course has been represented. "Miscellaneous crops" concern stubble carrots, spurry and lupines. On dry soils these special crops will do a little better than stubble turnips, though generally they may be less easily grown. Complementary they are mote frequently found on desiccating soils than elsewhere. Compared with turnips their total frequency remains only small.

The relation distinctly shows, that, with increasing humidity of the soil the percentage of second crops following the strongly reduced growing of rye will rise considerably.

From crop frequencies being found here, ratios can be derived which will have to mark the area after the water management has been improved, through which then any field will possibly be judged to be of good water retaining capacity.

With respect to the actual average, the following shiftings are likely to occur:

The proportion of permanent pasture to arable land is moving up from 1:3 up to 1:2, the proportion of pastures inclusive seeded grassland to arable land from 1:2 up to 2:2½, the proportion of cereals to root crops at last from 3:1 up to 2:1. The course of these proportions has been represented in figure 7.

The influence of the groundwater depth

a. The mean groundwater depth in summer:

Analogous to the procedure being followed with respect to soil humidity conditions, the influence of mean groundwater levels in summer upon the composition of the cropping pattern has been traced.

Frequencies - converted into per cent of total occurrence - in which, with the various classes of groundwater depth that have been distinguished by the COLN, the crops proved to be represented in the cropping pattern, have been surveyed in table 7A.

In figure 8, which gives an impression of the position of these computed frequency percentages with respect to the joint cropping curve, the parabolical shape shows to full advantage.

In this collective figure the horizontal axes of the originally separate logarithmic crop frequency figures have been redrawn at 10% frequency (=1).

In the same way as has been described with regard to soil humidity conditions, for any class of groundwater depth in summer the frequency of occurrence of the crops can be measured by means of a vertical logarithmic scale, of which, being moved up horizontally, the 10%- point has to be on a level with one of these axes every time.

Table 7A

Influence of the mean groundwater depth in summer upon the cropping pattern

groundwater depth in cm. below soil surface	Computed crop frequencies in per cent				
	40-70	70-100	100-140	140-200	>200
Crops:					
permanent pastures	63.2	43.2	31.6	23.6	4.5
seeded grassland	16.8	16.0	14.1	10.0	6.6
rye	6.4	11.4	18.0	24.3	38.6
potatoes	4.0	7.4	9.9	8.4	10.1
oats-barley m.c.	1.6	6.7	8.6	10.6	17.9
oats	3.2	6.6	7.9	14.4	12.3
fodder beets	4.0	7.5	7.2	4.6	3.2
corn	-	0.3	0.9	2.2	3.4
peas	-	-	0.3	0.7	1.8
miscellaneous	0.8	0.9	1.5	1.2	1.6
Total	100.0	100.0	100.0	100.0	100.0

After being plotted metrically against the mean groundwater depth, crop frequencies that have been measured off the cropping pattern parabola, will yield probability distribution curves such as have been represented in figure 9. In table 7B crop frequencies, converted to the parabola, have been summarized.

The shiftings within the cropping pattern caused by variations in groundwater levels in summer, show a similarity with those, that have been observed with respect to soil humidity conditions. A shallow groundwater level goes with a high frequency of grassland and a decrease of cereal growing as against an increase of root crops.

Table 7B

Influence of the mean groundwater level in summer upon the cropping pattern

	Crop frequencies converted to the parabola, in per cent									
groundwater depth in cm below soil surface	25	50	75	100	125	150	175	200	225	250
Crops:										
permanent pastures	62.8	57.3	49.0	39.0	31.0	22.4	15.7	10.4	6.7	4.0
seeded grassland	15.8	16.3	16.1	15.2	13.9	12.1	10.1	7.7	5.9	4.0
rye	3.6	6.0	9.1	13.3	18.0	23.0	28.2	32.8	35.0	37.0
potatoes	3.4	4.7	6.1	7.3	8.5	9.3	9.9	10.0	9.6	8.9
oats-barley m.c.	1.3	2.2	3.4	5.3	7.5	10.2	12.8	15.4	17.6	19.3
oats	2.3	3.5	5.1	6.9	8.7	10.6	11.9	13.0	13.5	13.4
fodder beets	7.0	7.3	7.4	7.2	6.7	5.9	4.9	3.8	3.0	2.1
corn	0.1	0.2	0.4	0.6	1.0	1.4	2.1	2.7	3.2	3.9
peas	-	-	0.1	0.2	0.3	0.5	0.8	1.1	1.6	2.1
miscellaneous	0.5	0.7	0.9	1.1	1.3	1.4	1.5	1.5	1.5	1.4

The frequency of stubble crops after rye growing proves to vary only slightly. The optimum occurs at a groundwater depth of about 120 cm below soil surface. In table 8 frequencies have been given at various classes of mean groundwater depth in summer..

Table 8

Influence of the groundwater level in summer upon the frequency of stubble crops after rye growing

	Frequency of occurrence after rye in per cent				
groundwater depth in cm. below soil surface	40-70	70-100	100-140	140-200	>200
Crops:					
stubble turnips	-	43.3	41.5	38.5	40.7
clovers	-	-	6.7	2.4	0.5
miscellaneous	-	-	1.0	1.7	2.7
	-	43.3	49.2	42.6	43.9

The course of these crop frequencies has been represented in figure 10. Within the class of 40-70 cm. below soil surface no second crops have been observed. Apart from that it is thus that as an average in summer, the class of 70-100 cm.b.s.s. occurs but little, the class of 40-70 cm. b.s.s. practically not at all. So the relation between the percentage of stubble crop after rye growing and the groundwater level has to appear especially from the stretch of 100 cm below soil surface and deeper.

b. The mean groundwater depth in winter

The influence of the mean groundwater depth in winter has been derived in the same way as has been done with respect to the one in summer. Crop frequencies being expressed in per cent of total occurrence are given in table 9A, whereas in table 9B these frequencies have been given after being converted to the cropping parabola.

Table 9A

Influence of the mean groundwater level in winter upon the cropping pattern

groundwater depth in cm. below soil surface	computed crop frequencies in per cent 20	55	85	.120	200
Crops:					
permanent pastures	53.0	34.3	16.9	5.2	3.9
seeded grassland	17.0	12.7	9.0	6.8	5.6
rye	8.1	18.0	28.6	34.3	42.4
potatoes	4.8	8.3	9.3	10.6	10.2
oats-barley m.c.	4.5	8.2	14.0	17.9	14.3
oats	4.6	9.1	13.3	13.9	14.6
fodder beets	6.1	5.9	4.7	4.0	2.8
corn	0.4	1.2	2.2	3.3	3.7
peas	-	0.7	1.0	1.1	1.3
miscellaneous	1.5	1.6	1.0	2.9	1.2
Total	100.0	100.0	100.0	100.0	100.0

Table 9B

Crop frequencies converted to the parabola, in per cent

groundwater depth in cm. below soil surface	10	30	55	85	100	120	150	170	200
Crops:									
permanent pastures	54.0	43.0	31.5	20.0	14.7	9.8	4.1	2.0	0.0
seeded grassland	15.0	14.8	13.4	11.2	10.1	8.0	5.5	4.0	2.2
rye	7.2	10.8	16.7	24.5	28.5	33.6	40.0	43.0	43.0
potatoes	4.5	6.0	7.5	9.3	10.2	10.8	11.0	10.6	9.2
oats-barley m.c.	4.7	6.5	9.8	12.2	13.6	15.0	16.8	17.0	15.8
oats	4.8	6.6	9.3	11.9	13.3	14.7	15.9	16.0	14.8
fodder beets	6.0	6.2	5.9	5.0	4.6	3.8	3.8	2.1	1.2
corn	0.5	0.8	1.2	2.0	2.3	2.8	3.4	3.7	4.0
peas	0.3	0.5	0.7	0.9	1.0	1.2	1.3	1.3	1.2
miscellaneous	1.2	1.7	2.0	2.2	2.3	2.2	2.0	1.8	1.4

The position of the computed frequency percentages with respect to the cropping pattern parabola has been represented in figure 11. Though this position is definitely inferior to the one regarding the mean groundwater depth in summer, the particular shape of the joint cropping curve is sufficiently showing yet. The abscissae of the original logarithmic crop frequency figures have been drawn in the same collective figure. Probability distribution curves, drawn for each separate crop, have been represented in figure 12.

Fundamentally the frequency of occurrence of stubble crops after rye growing is influenced by the groundwater level in winter in just the same way as by that in summer, provided, all along winter levels will be of lower value of course.

In table 10 these frequencies have been summarized.
The relation has been represented in figure 13.

Table 10

Influence of the groundwater level in winter upon the frequency of stubble crops after rye growing

groundwater depth in cm. below soil surface	Frequency of occurrence after rye in per cent				
	20-40	40-70	70-100	140-200	>200
Crops:					
stubble turnips	41.2	40.0	42.2	36.3	22.2
clovers	9.5	2.2	1.4	0.0	-
miscellaneous	0.1	0.2	1.7	0.0	-
Total	50.8	42.4	45.3	36.3	22.2

THE OPTIMAL GROUNDWATER LEVEL OF THE UNDULATING SANDY BORDERLAND OF THE DELTA

The results of these three analogical operations, being embodied in the figures 5, 9 and 12, demonstrate a strong conformity between the cropping pattern being influenced by the groundwater level in summer or winter on one side, the practical opinion of the mean humidity condition of the soil on the other. The significance of the judgment on the humidity condition of his fields being given by the farmer himself is, a judgment like that cannot possibly be based on physical soil properties only, but must be strongly correlated with the agricultural value of the soil. "Too wet" or "too dry" therefore has no reference to the moisture content of the soil being too small or too large in the proper sense, but implies a condemnation by reason of the limited possibility of agricultural use. If the farmer judges certain fields to be of good water retaining capacity, this actually means, from the point of view of crop growing these soils will be neither too wet nor too dry.

Moreover, however, this judgment implies the possibility of optimal agricultural use. Within the bounds of the area concerned, soils that have been judged to be of prime hydrological quality will prove to be of the highest productivity at the same time.

Consequently, the average cropping pattern that has been proved to exist with these prime soils, will mark the optimal crop ratios. So mean groundwater levels in summer and winter, going with the humidity condition of "good water retaining capacity" may be considered the optimal groundwater depth within this area.

a. Derivation of the optimal groundwater depth

In order to trace the optimal groundwater depth, the scales for groundwater depth and humidity condition have to be synchronized.

To that end, from figures 5, 9 and 12 it has been measured at which humidity condition of the soil as well as at which groundwater level in summer and winter each separate crop will have its optimal frequency, respectively a certain percentage of its optimal frequency.

By plotting these data in a graph, in which the scale for groundwater depth has been marked on one axis, that for humidity condition on the other, two straight lines are obtained, which represent the relation between humidity condition and mean groundwater level for summer and winter respectively. Now from these lines can be read with which mean groundwater depth each of the distinguished humidity conditions will cohere. This procedure has been represented in figures 14A up to and including 14D.

In table 11, in which the results have been summarized, it has been marked at which mean groundwater depth in summer and winter

a. each crop is grown most frequently,
b. from a point of view of growing this special crop, may be spoken of "prime" fields.

These two facts have to be kept well apart. It has been pointed out before, the highest frequency with which a crop occurs, mostly does not coincide with such farming conditions as may be considered optimal for growing this special crop, for actually a crop will be most frequently grown under conditions where its productiveness is proved to be relatively higher than that of the other crops out of the usual assortment. The reason why rye is grown most on distinctly dry soils is, this crop will do better here than oats or root crops will. Naturally the best fields for rye growing will be those, which have a good water management, but here the crop is supplanted by crops of higher productivity that won't do on dry soils.

In table 11 this distinction has been described by means of the terms "optimal farming condition of the soil" and "highest frequency" respectively.

Table 11

Mean groundwater depth in case of highest frequency of crops and optimal farming condition of the soil respectively

crops	mean groundwater depth in cm. below soil surface			
	highest frequency at:		optimal farming condition of soil at:	
	winter	summer	winter	summer
Cereals: rye	185	287	50	120
oats	160	237	52	130
oats-barley m.c	167	285	65	145
Root crops:				
potatoes	142	195	67	117
fodder beets	30	70	65	120
Miscell.: corn	205	330	55	130
peas[1)]	170	372	-	-
Grassland:				
seeded grassl.	15	57	50	105
perm.pastures	periodically flooded[2)]		60	130

Explanation: [1)]Due to the extremely low frequency of peas, the probability distribution curve is almost straight here

[2)]In the column "highest frequency", going with the optimum of the probability distribution, with permanent pastures negative values of mean groundwater depth occur. Theoretically this will be right, since periodically flooded land such as land outside the dikes as well as foreland, which hydrologically seen may be considered the extreme of possibilities of agricultural use, ever completely consists of pasture.

Regarding the values of mean groundwater depth in summer and winter, marking the optimal farming conditions of the soil, from crop to crop some variation occurs. A mean shallowest groundwater level (winter months) of 50-60 cm below soil surface coupled with a mean deepest level (summer months) of 120-130 cm. below soil surface has to be considered here the most favourable groundwater depth in the circumstances.

b. Cropping pattern identity

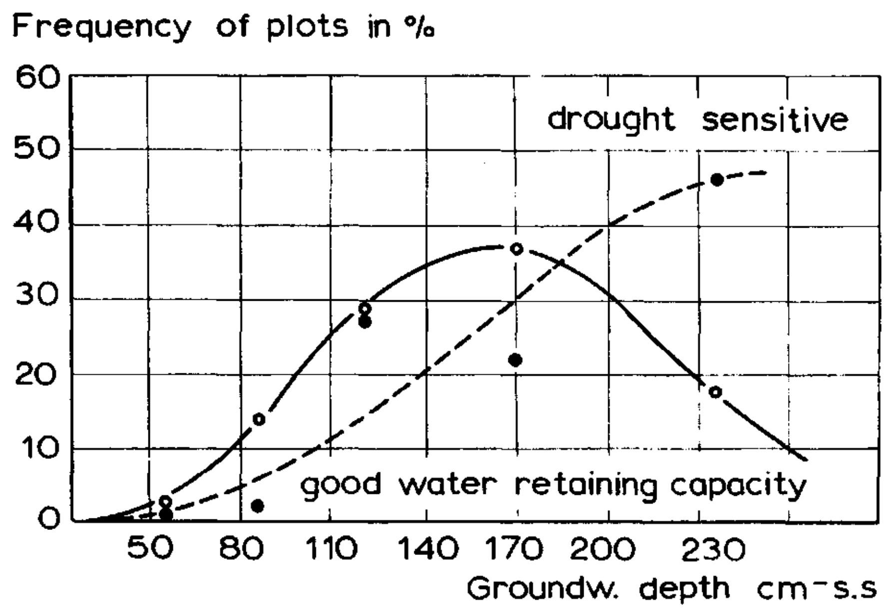
The measure of similarity between crop ratios, such as have been derived for the humidity class of "good water retaining capacity" and for a mean groundwater depth of 120-130 cm.b.s.s. in summer as well as of 50-60 cm. in winter respectively, decides how far synchronization of the scales for humidity condition and groundwater depth has succeeded. This similarity is the actual criterion for the correctness of the groundwater levels in question being considered optimal.

Crop frequencies going with the humidity condition of "good water retaining capacity" have been given in table 5B. Those which go with a mean deepest groundwater level of 120-130 cm.b.s.s. are found in table 7B in the column of 125 cm, those which go with a mean shallowest level of 50-60 cm.b.s.s. in table 9B in the column of 55 cm.

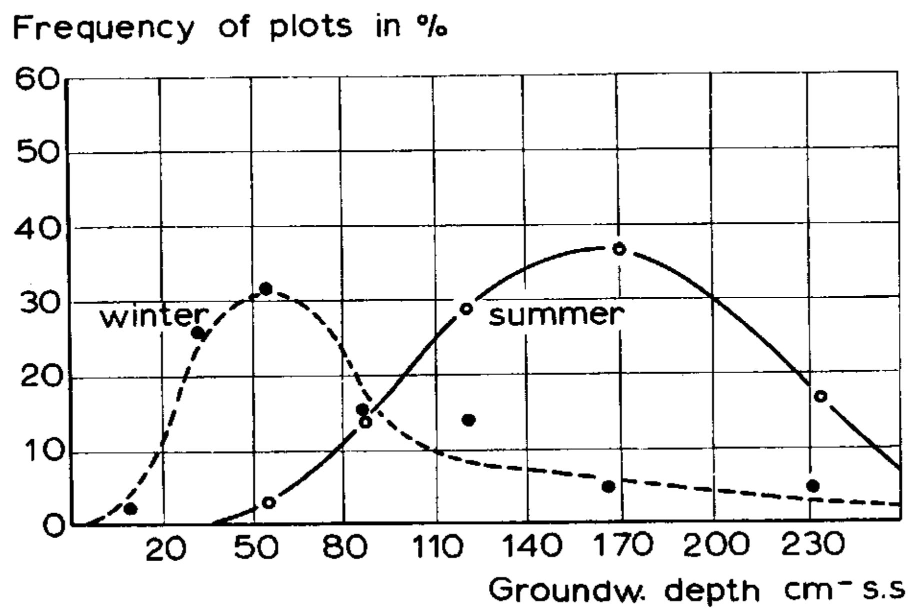
For comparison these frequencies have summarized in table 12. The measure of similarity between the three cropping patterns has been represented in figure 15.

Table 12 Crop ratios being derived for sandy soils of good water retaining capacity, for sandy soils with a mean groundwater depth of 125 cm.b.s.s. in summer and of 55 cm.b.s.s. in winter respectively

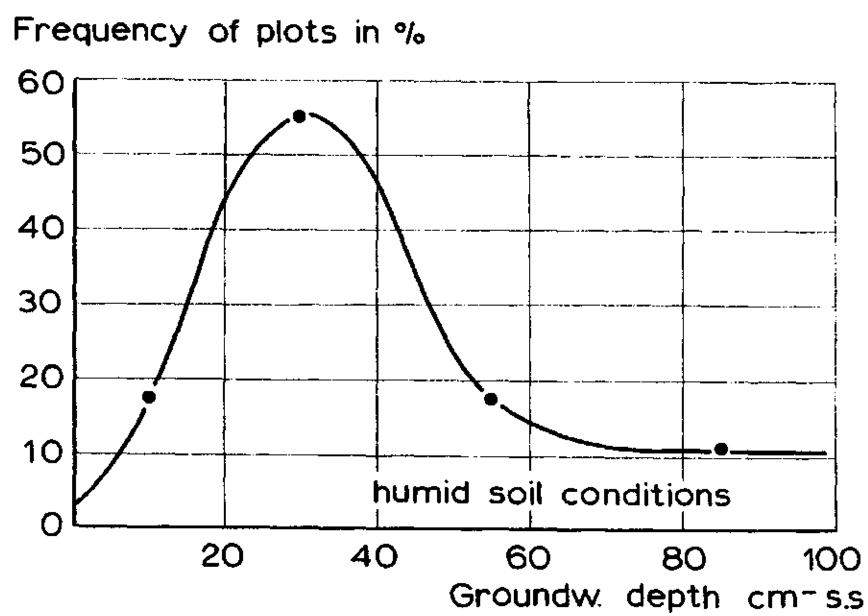
crops	good water retaining capacity	groundwater depth in summer 125 cm.b.s.s.	groundwater depth in winter 50 cm.b.s.s.
permanent pastures	31.0	31.0	31.5
seeded grassland	13.4	13.9	13.4
rye	16.9	18.0	16.7
potatoes	8.8	8.5	7.5
oats-barley m.c.	9.7	7.5	9.8
oats	8.4	8.7	9.3
fodder beets	6.5	6.7	5.9
corn	1.3	1.0	1.2
peas	0.5	0.3	0.7
miscellaneous	1.2	1.3	2.0

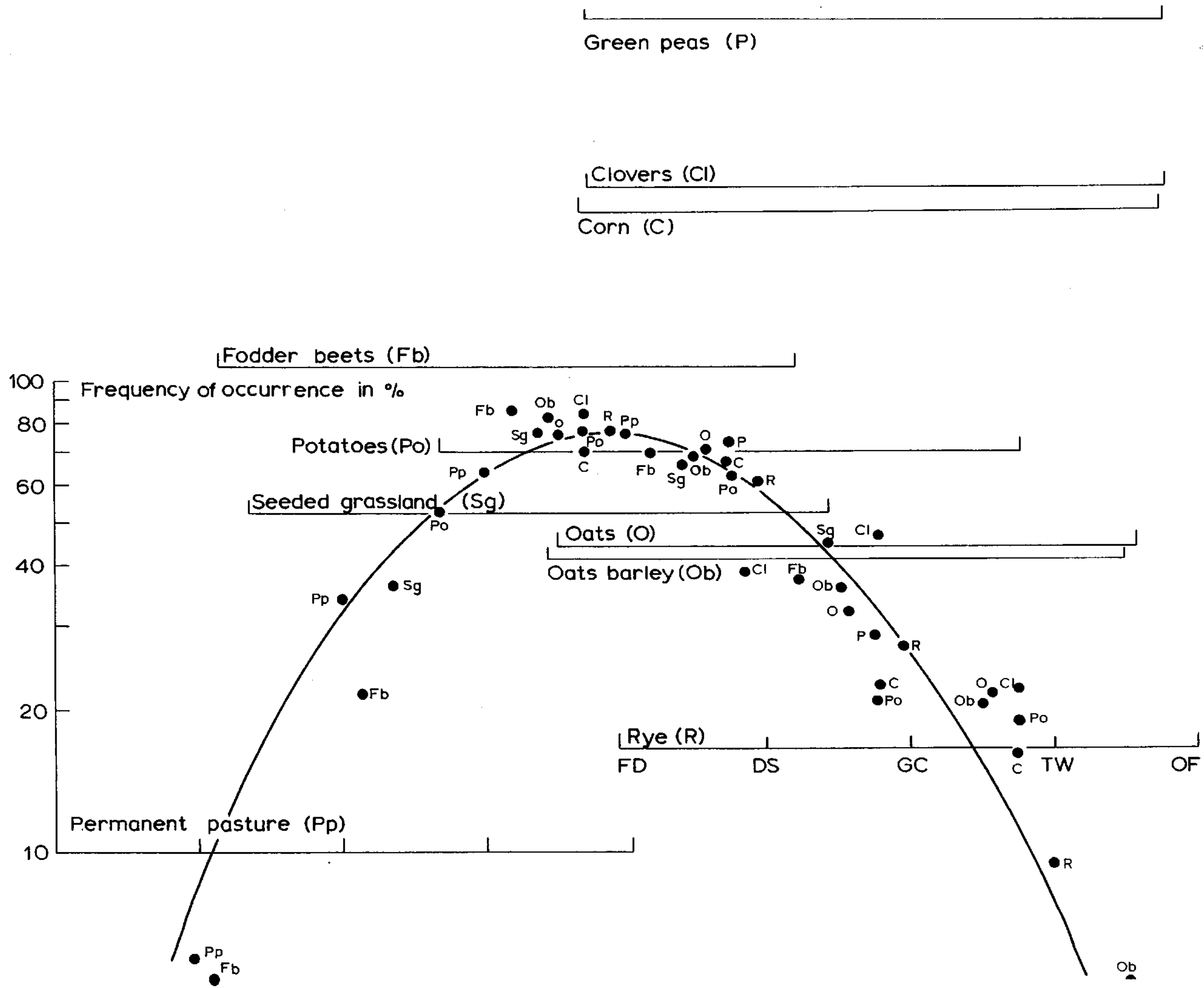

Frequency of plots in %
60
50
40
30
20
10
0
drought sensitive
good water retaining capacity
50
80
110
140
170
200
230
Groundw. depth cm-s.s

61C/145-1

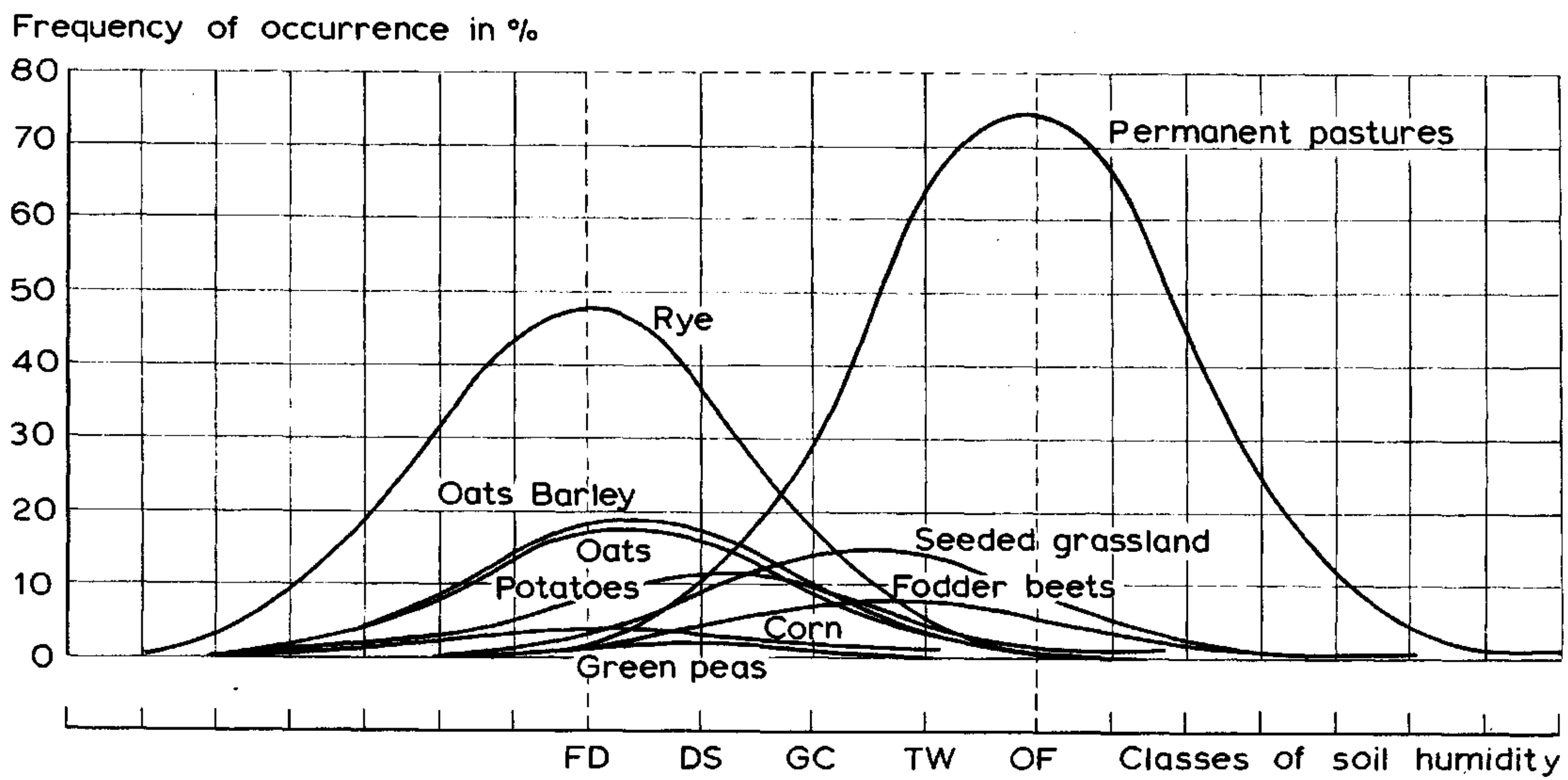

Frequency of plots in %
60
50
40
30
20
10
0
winter
summer
20
50
80
110
140
170
200
230
Groundw. depth cm⁻ s.s

61C/145-2

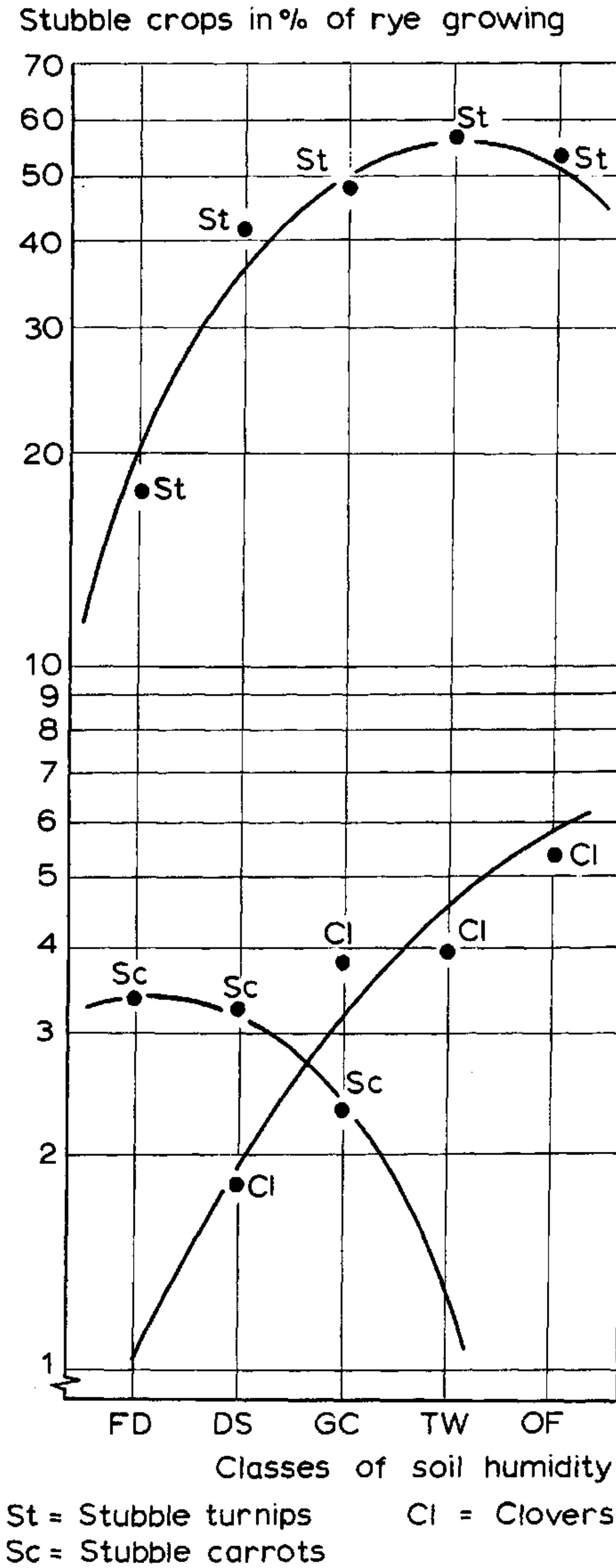

Frequency of plots in %
60
50
40
30
20
10
0
20
40
60
80
100
Groundw. depth cm⁻s.s
humid soil conditions

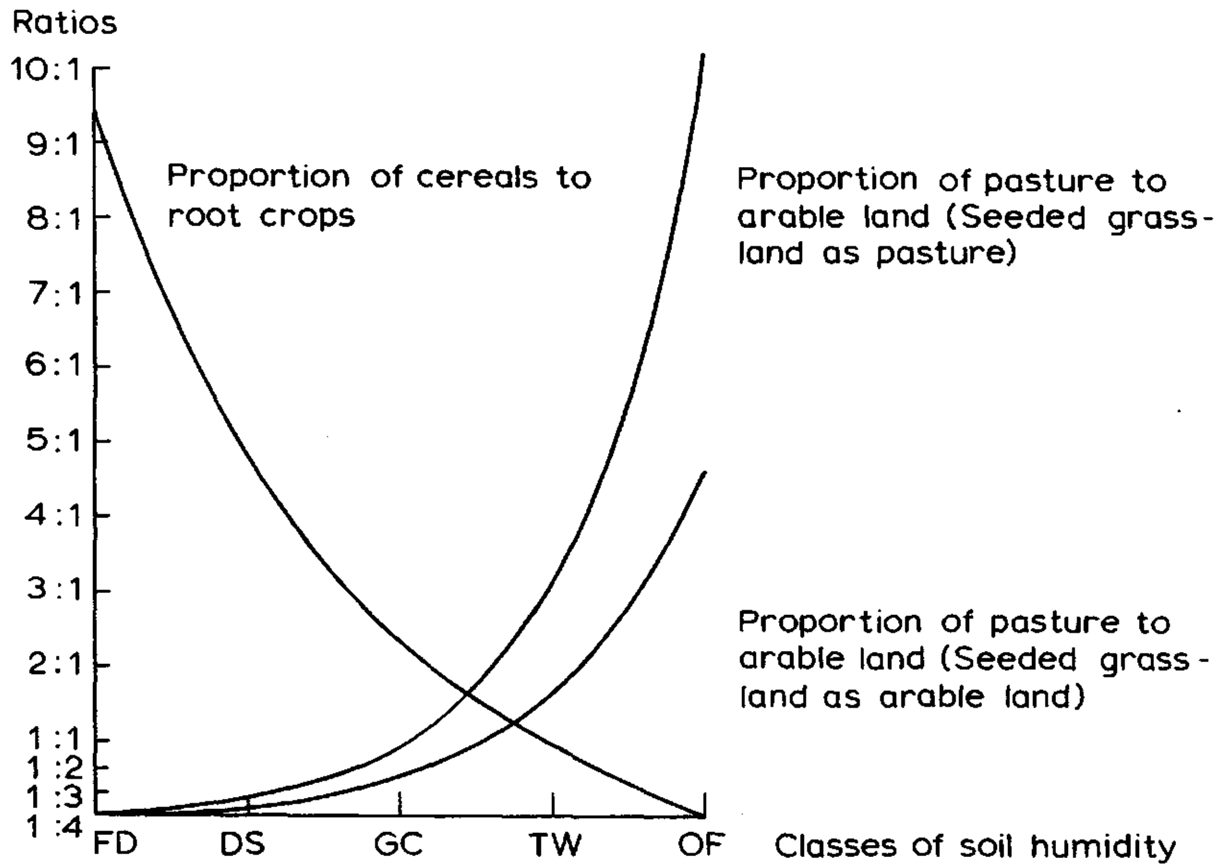

Green peas (P)
Clovers (Cl)
Corn (C)
Fodder beets (Fb)
Frequency of occurrence in %
Potatoes (Po)
Seeded grassland (Sg)
Oats (O)
Oats barley (Ob)
Rye (R)
Permanent pasture (Pp)
100
80
60
40
20
10
FD
DS
GC
TW
OF

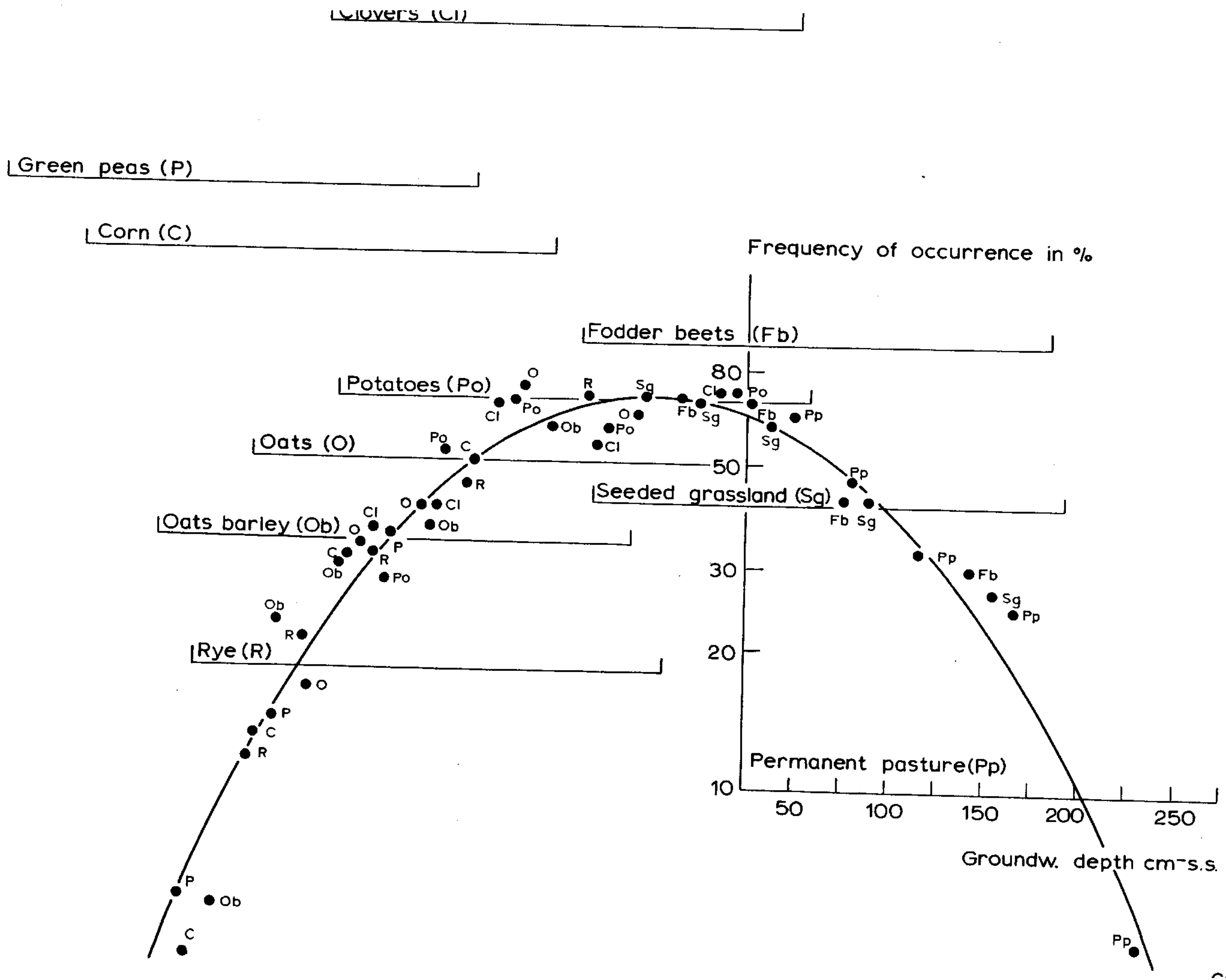
61C/145-15

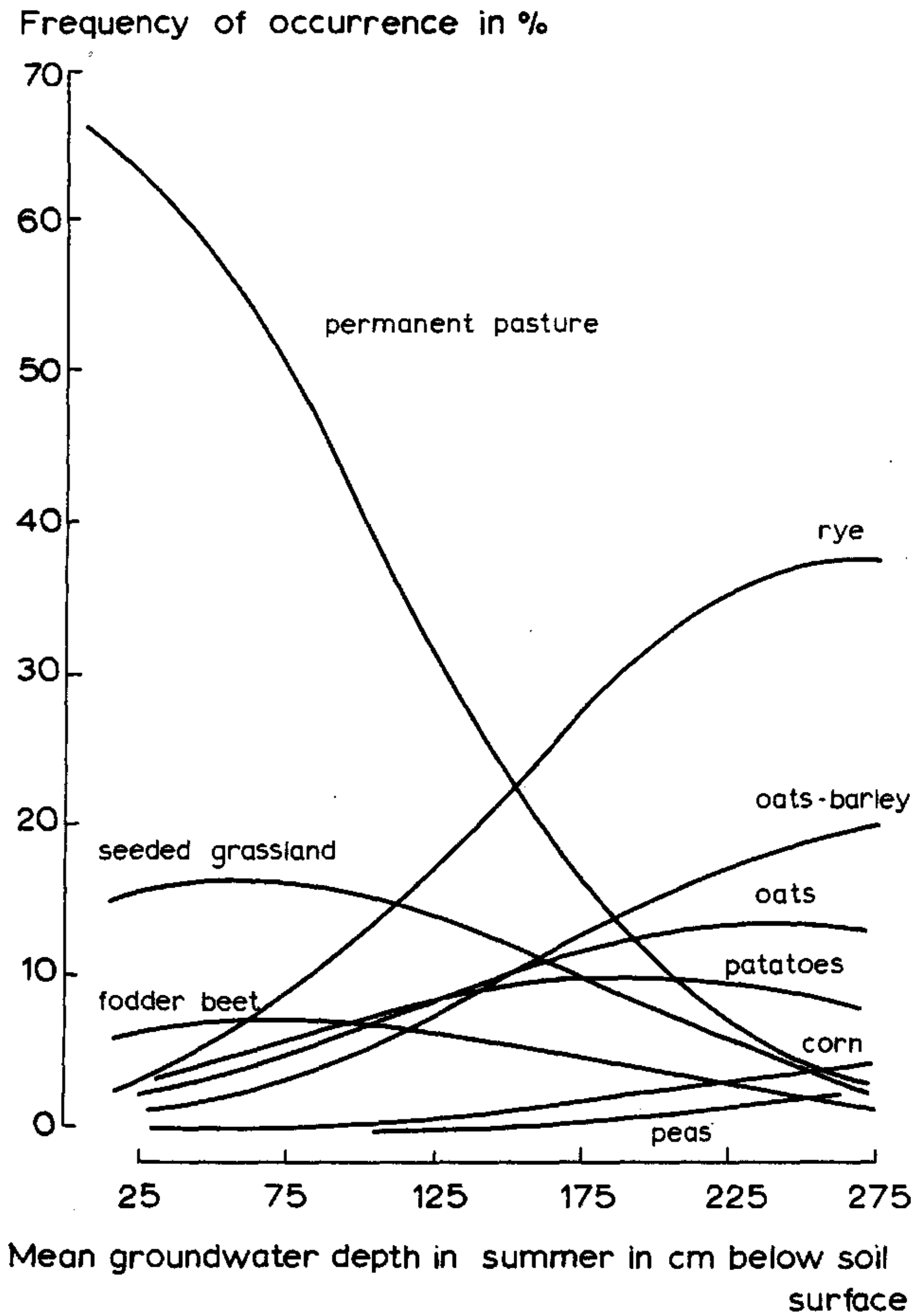

Frequency of occurrence in %
80
70
60
50
40
30
20
10
0
Permanent pastures
Rye
Oats Barley
Oats
Potatoes
Seeded grassland
Fodder beets
Corn
Green peas
FD
DS
GC
TW
OF
Classes of soil humidity

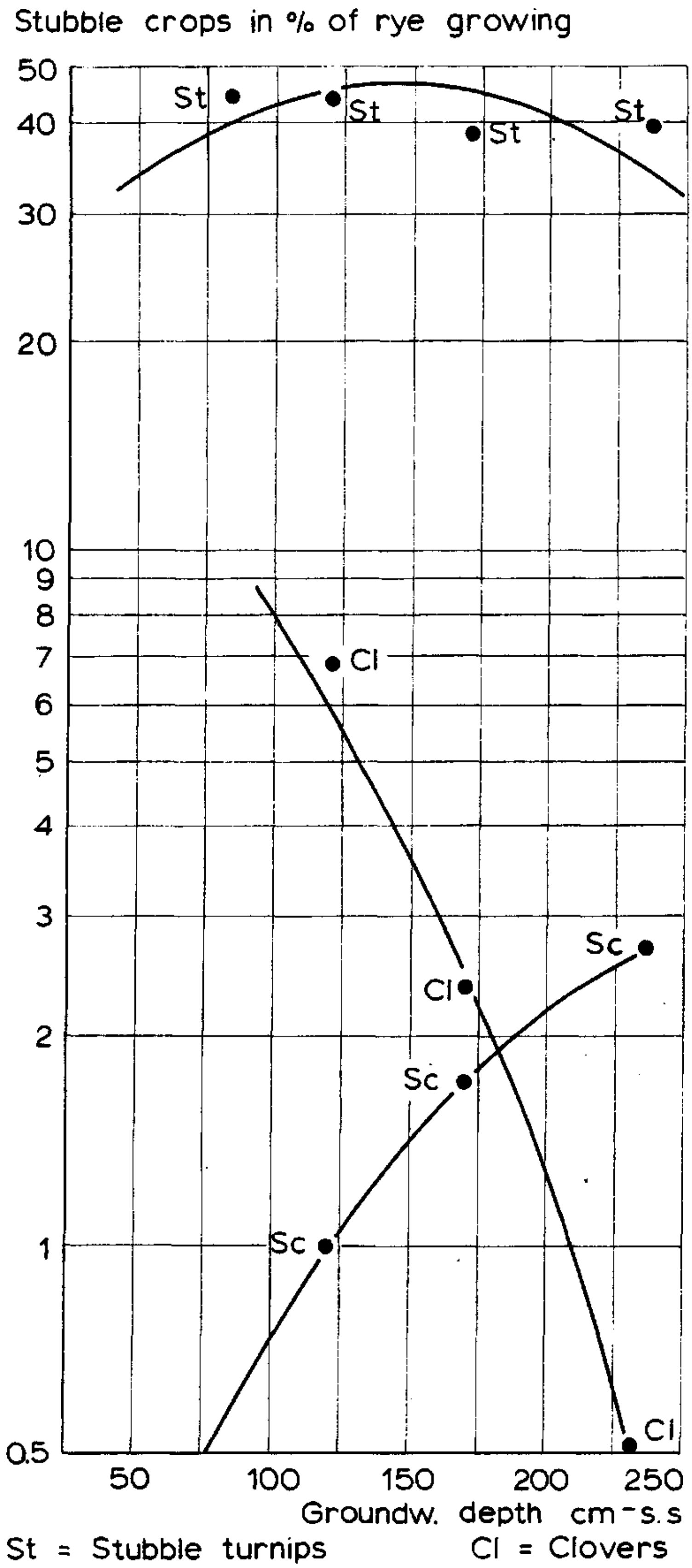
61C/145-4


Stubble crops in % of rye growing
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
St
Sc
Cl
FD
DS
GC
TW
OF
Classes of soil humidity
St = Stubble turnips
Sc = Stubble carrots
Cl = Clovers

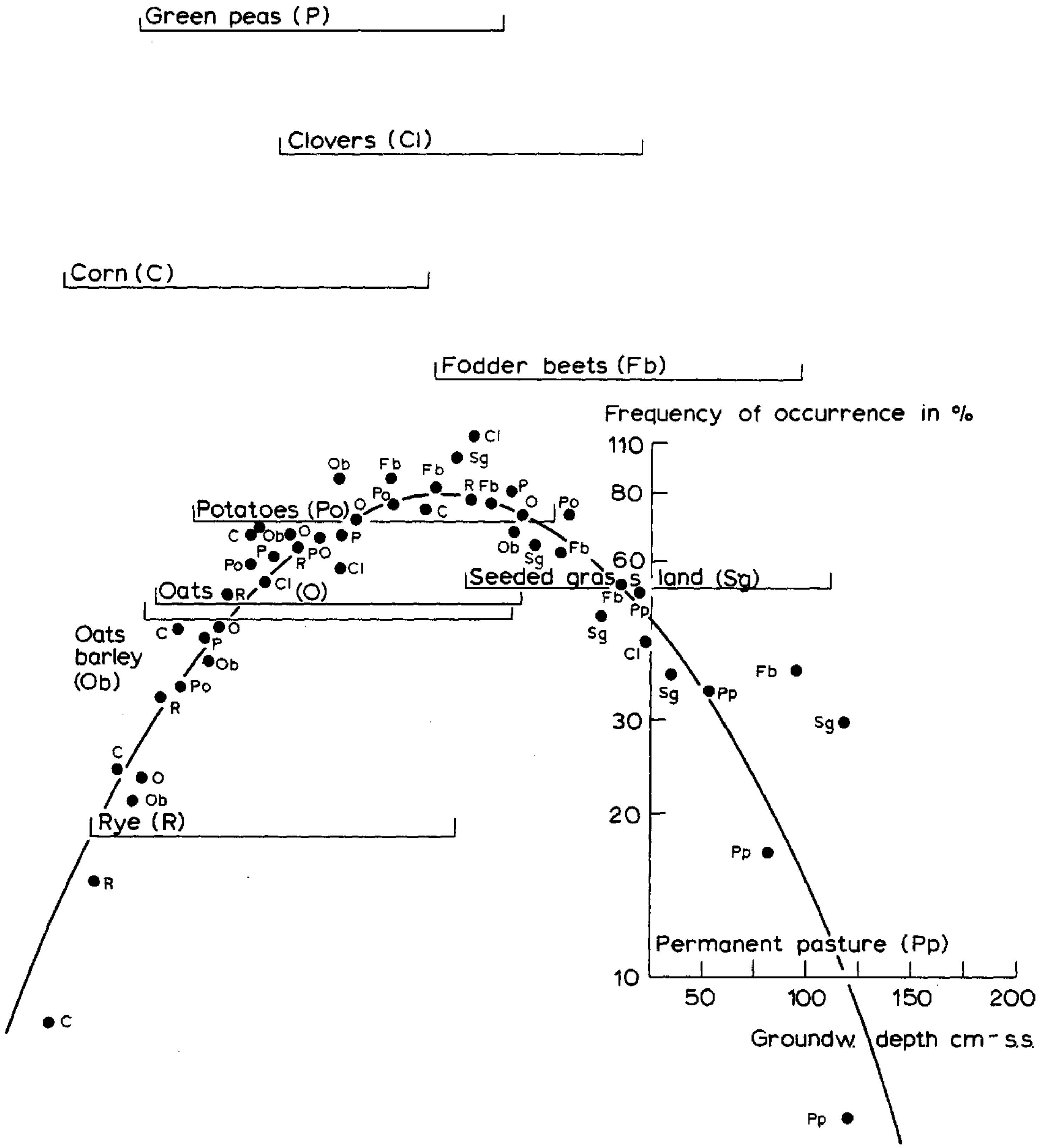

Ratios
10:1
9:1
8:1
7:1
6:1
5:1
4:1
3:1
2:1
1:1
1:2
1:3
1:4
Proportion of cereals to root crops
Proportion of pasture to arable land (Seeded grass-land as pasture)
Proportion of pasture to arable land (Seeded grass-land as arable land)
FD
DS
GC
TW
OF
Classes of soil humidity

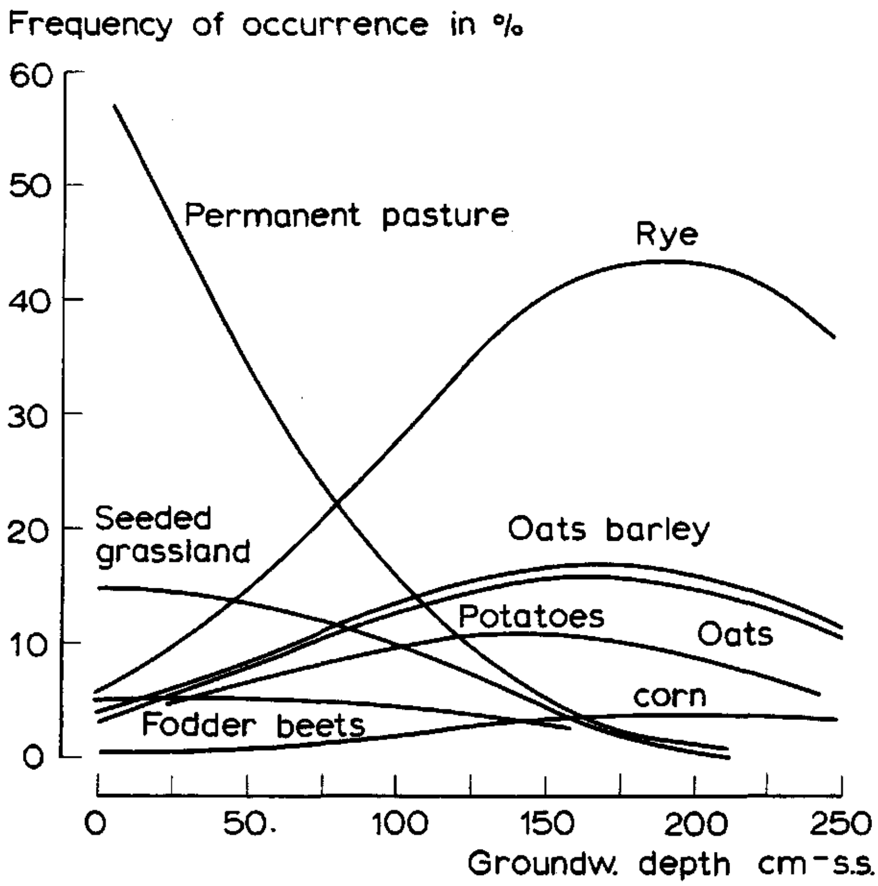

Clovers (Cl)
Green peas (P)
Corn (C)
Frequency of occurrence in %
Fodder beets (Fb)
Potatoes (Po)
Oats (O)
Seeded grassland (Sg)
Oats barley (Ob)
Rye (R)
Permanent pasture (Pp)
80
50
30
20
10
50
100
150
200
250
Groundw. depth cm-s.s.

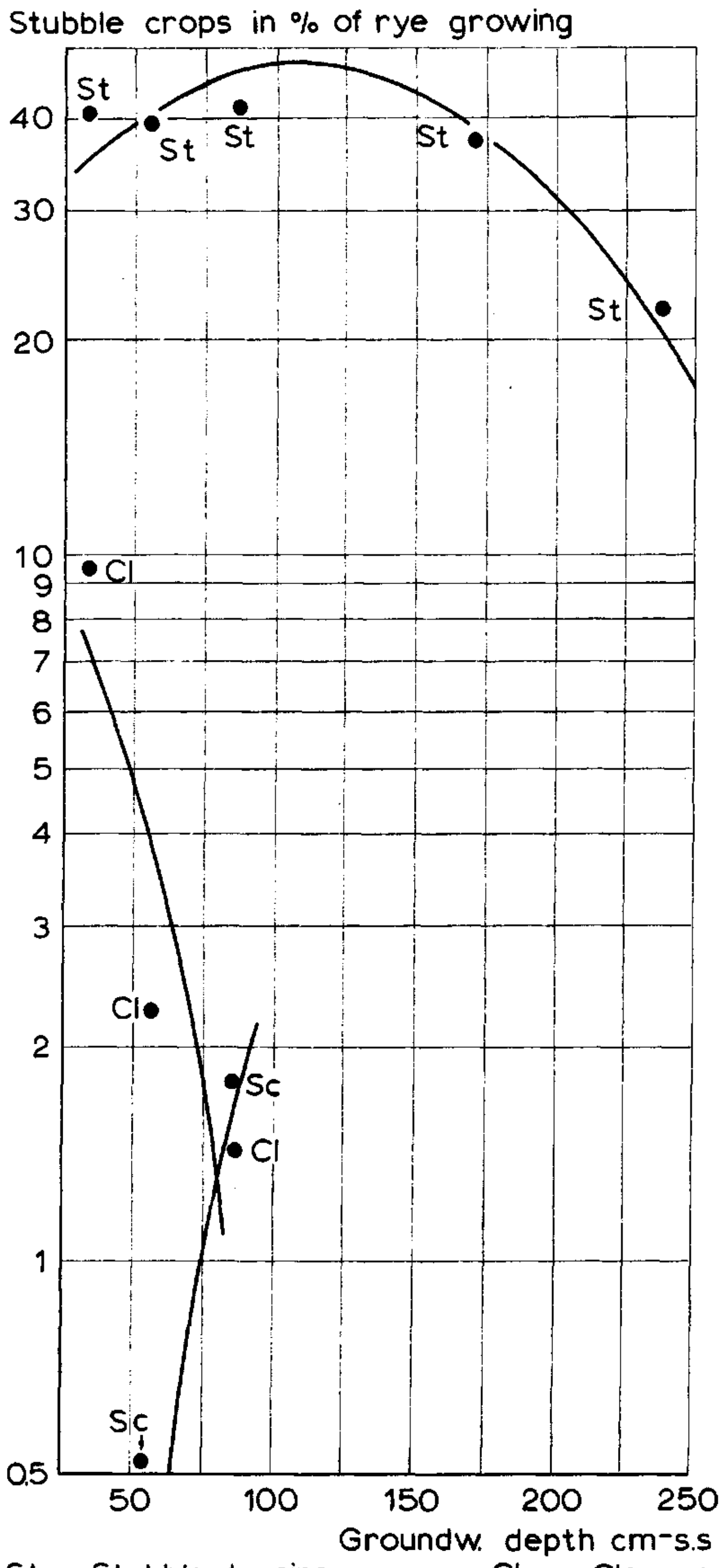

Frequency of occurrence in %
70
60
50
40
30
20
10
0
permanent pasture
rye
oats-barley
seeded grassland
oats
patatoes
fodder beet
corn
peas
25
75
125
175
225
275
Mean groundwater depth in summer in cm below soil surface



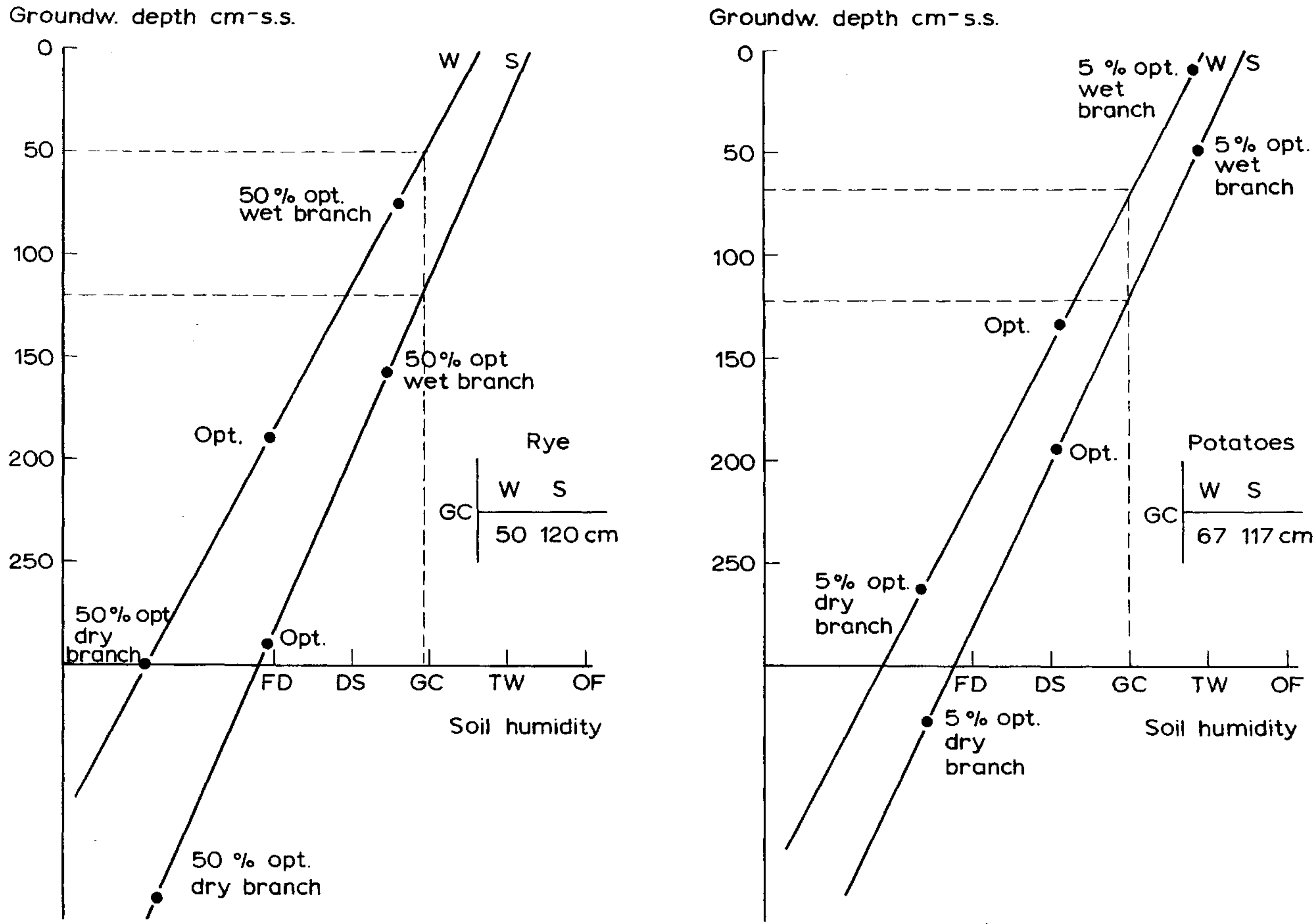
St = Stubble turnips
Sc = Stubble carrots
Cl = Clovers


Green peas (P)
Clovers (Cl)
Corn (C)
Fodder beets (Fb)
Frequency of occurrence in %
Potatoes (Po)
Oats (O)
Oats barley (Ob)
Seeded grass land (Sg)
Rye (R)
Permanent pasture (Pp)
110
80
60
30
20
10
50
100
150
200
Groundw. depth cm - s.s.

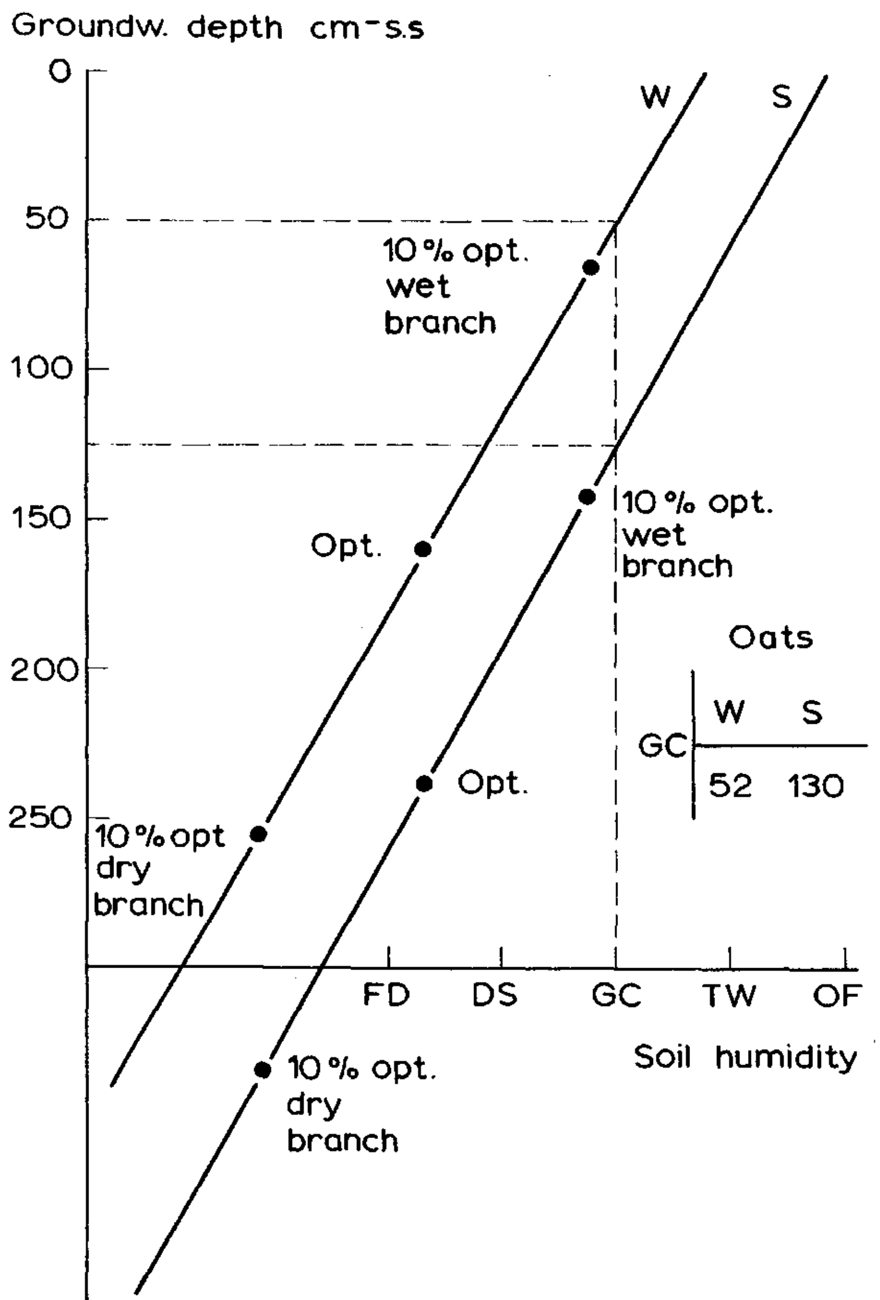

Frequency of occurrence in %
60
50
40
30
20
10
0
Permanent pasture
Rye
Seeded
grassland
Oats barley
Potatoes
Oats
corn
Fodder beets
0
50.
100
150
200
250
Groundw. depth cm-s.s.

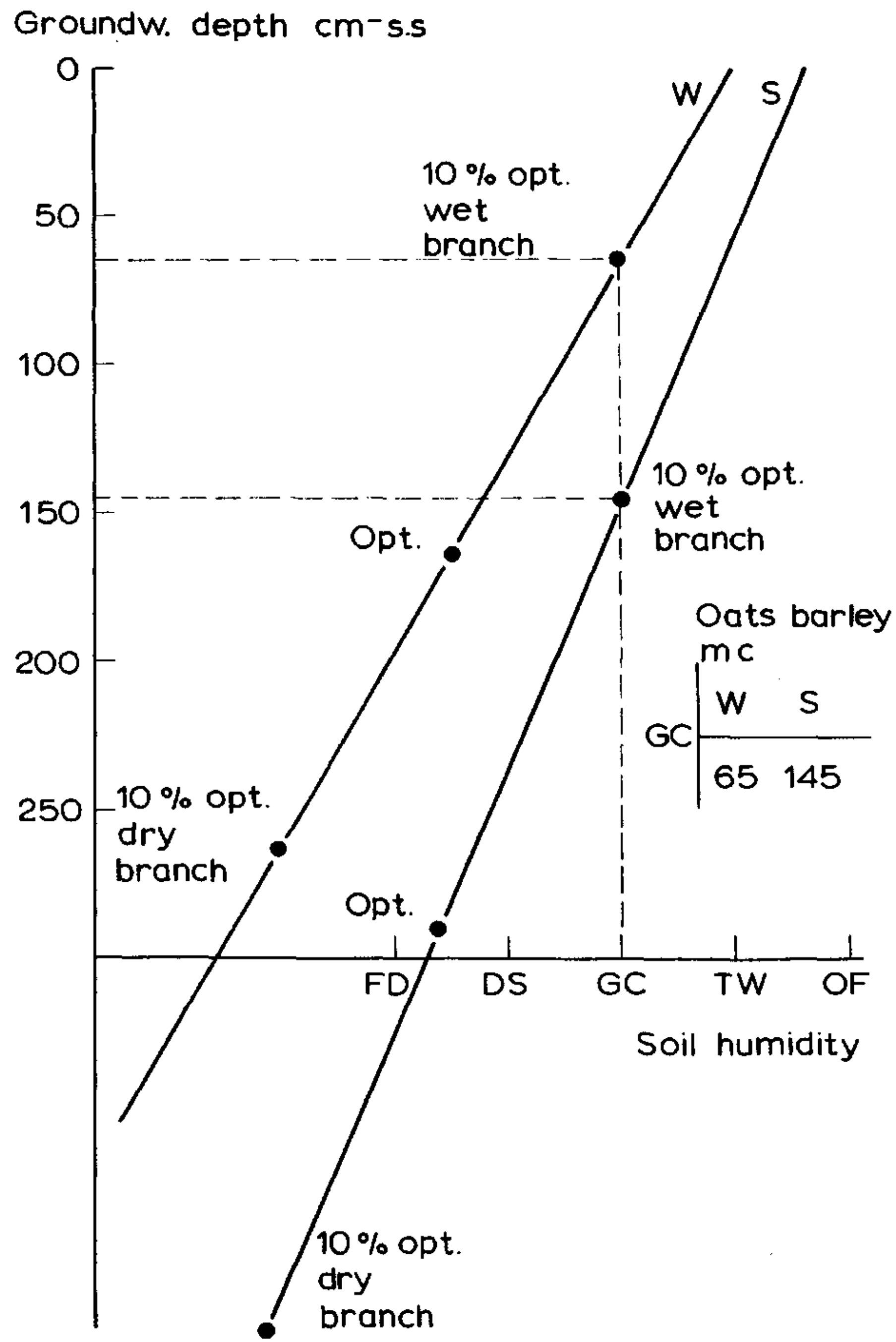


St = Stubble turnips Cl = Clovers
Sc = Stubble carrots

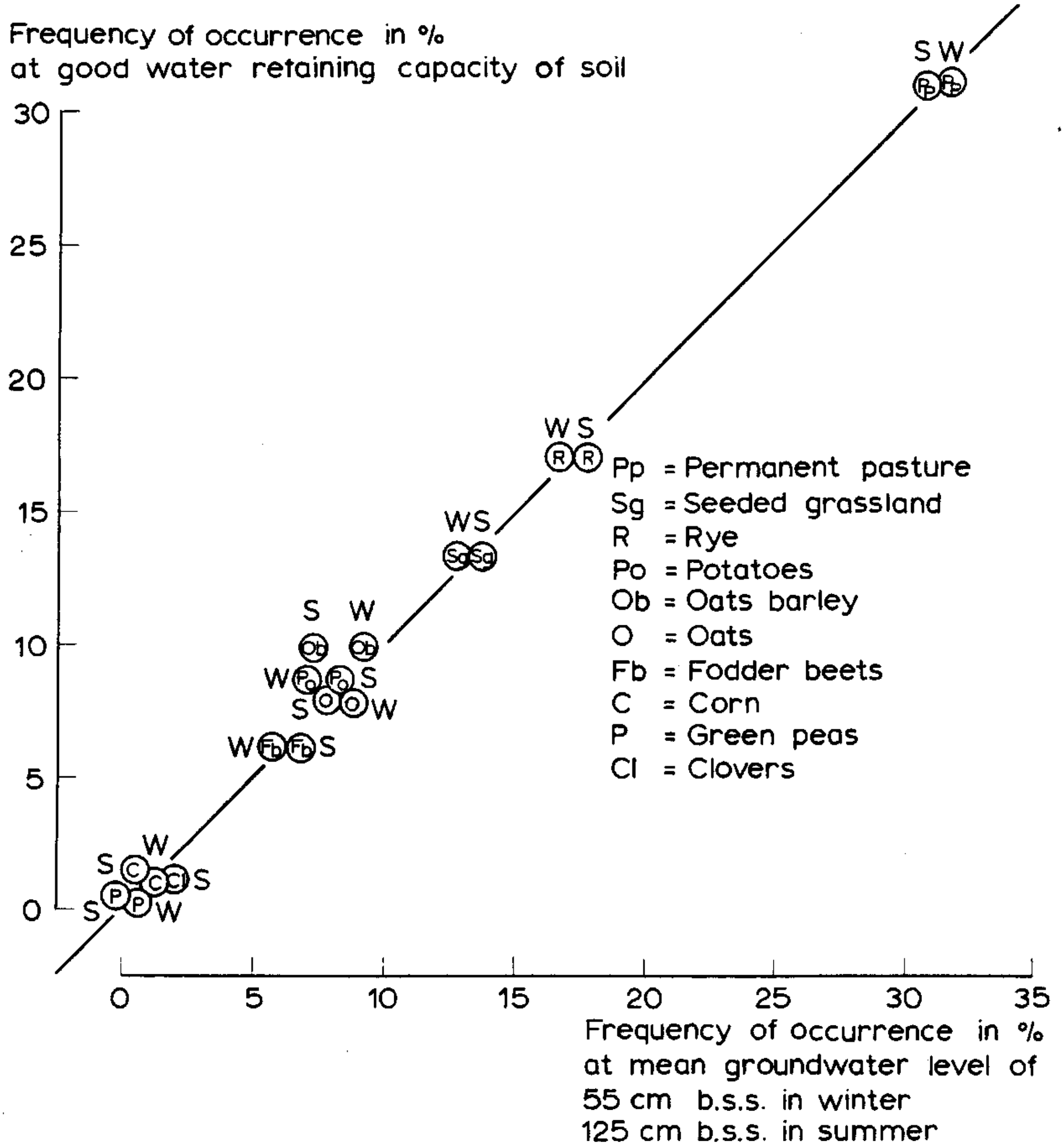

Groundw. depth cm-s.s.
0
50
100
150
200
250
W
S
50 % opt. wet branch
50 % opt wet branch
Opt.
Opt.
50 % opt dry branch
50 % opt. dry branch
Rye
GC
W S
50 120 cm
FD
DS
GC
TW
OF
Soil humidity
Groundw. depth cm-s.s.
0
50
100
150
200
250
5 % opt. wet branch
W
S
5 % opt. wet branch
Opt.
Opt.
Potatoes
GC
W S
67 117 cm
5 % opt. dry branch
5 % opt. dry branch
FD
DS
GC
TW
OF
Soil humidity

61C/145-10


Groundw. depth cm-s.s
0
50
100
150
200
250
W
S
10 % opt. wet branch
Opt.
10 % opt. wet branch
Oats
GC
W S
52 130
Opt.
10 % opt dry branch
10 % opt. dry branch
FD DS GC TW OF
Soil humidity


Groundw. depth cm-s.s
0
50
100
150
200
250
W
S
10 % opt. wet branch
10 % opt. wet branch
Opt.
Oats barley mc
GC
W S
65 145
10 % opt. dry branch
Opt.
10 % opt. dry branch
FD DS GC TW OF
Soil humidity

61C/145-11


Frequency of occurrence in %
at good water retaining capacity of soil
30
25
20
15
10
5
0
0
5
10
15
20
25
30
35
Frequency of occurrence in %
at mean groundwater level of
55 cm b.s.s. in winter
125 cm b.s.s. in summer
Pp = Permanent pasture
Sg = Seeded grassland
R = Rye
Po = Potatoes
Ob = Oats barley
O = Oats
Fb = Fodder beets
C = Corn
P = Green peas
Cl = Clovers