Moisture indication on grassland by vegetation and soil: a comparison of maps

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Summary

The soil and grassland-vegetation maps of the area shown in the *figure* are compared statistically. The soil in this area consists of sandy soil, peat soil, clay soil, sandy soil with a peat cover, sandy soil with a clay cover, peat soil with a clay cover, peat soil with a clay cover and a sandy subsoil. The sandy soils only are subdivided into moisture classes, mainly based on the ground-water characteristics of the soil.

The vegetation map shows how the grassland is divided up into moisture classes according to the botanical composition of the sward.

The relation was studied between soil types and soil-moisture classes on the one hand and moisture classes according to vegetation on the other. This is done by noting which soil type, soil-moisture class and vegetation-moisture class coincide at a great number of regularly distributed points.

The results can be summarized as follows : –

1. Soil types often differ with regard to the distribution of points over the vegetation-moisture classes. The differences between soil types varying in one factor influencing moisture supply are usually slight and do not always have the trend that might be expected as a result.

From the material available it is not always possible to determine for certain whether these differences are due to differences in the typical soil characteristics, or to diversity in the depth of ground water caused by systematic differences in altitude.

Most likely, however, typical soil proporties have proportionally the greatest influence on soil types with a low moisture capacity (*tables* 1, 2 and 3).

2. In proportion to other soils sandy soil types show a much greater difference in relative height. Accordingly, the dispersion of the points over the vegetation-moisture classes is fairly wide.

Subdivision into soil-moisture classes reduces this distribution range to about the same level as in some other light soil types. Variation of soil-moisture class within the same soil type shows a distinct difference in distribution of points over the vegetation-moisture classes.

The distribution of the points over the vegetation-moisture classes (*tables* 6, 7 and 8) is hardly affected by subdividing all points belonging to a soil-moisture class on the basis of soil types and varying the soil type within one soil-moisture class.

3. A clear, although not very close correlation was found between the soil-moisture classes and the vegetation-moisture classes. This correlation seems to be closer as the site is wetter. This means that the water table in relation to other properties of the habitat is more significant for the vegetation as the site is wetter (*table* 9).

However, since even the points belonging to one soil type and one soil-moisture class are often dispersed over a fairly wide range of vegetation-moisture classes, soil type and soil-moisture class together, as defined here, do not satisfactorily explain the vegetation-moisture classes that are found.

4. Combined pedological and phytosociological research is required on this subject.

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1. Introduction

As the water supply is a very important factor for plant growth, the characterization of the moisture condition of a site is an important feature of a soil and vegetation survey made for agricultural purposes.
In the Netherlands the moisture condition of grassland can be assessed by means of the vegetation. This method is based on the fact that certain plant species, *i.e.* moisture indicators, indicate a surplus of water in the plot, while others, which are drought indicators, indicate a certain water deficiency. Moreover, there is a correlation between the abundance of the indicator in the vegetation and the extent of the deficiency or surplus. In this way it is possible to distinguish eight different vegetation-moisture classes (DE BOER, 1956a, b; DE VRIES & DE BOER, 1956).
The Soil Survey Institute in the Netherlands publishes soil maps showing several soil types, special attention being paid to factors influencing the moisture conditions, *e.g.* silt and humus content. Nevertheless, it was felt to be a drawback that certain soil types, especially the sandy soils, showed a wide variation in agricultural properties due to different depths of the water table. These soil types were subdivided into seven soil-moisture classes according to the ground-water characteristics of the soil (WESTERVELD, 1958).
In 1956 and 1957 both soil and grassland vegetation were surveyed in an area between the hills of the Veluwe and the Veluwemeer, a part of the former Zuiderzee (Anon., 1958; WESTERVELD, 1958). It is interesting to see how far the data on moisture conditions are related in these two maps.
An attempt will be made to answer the following questions: –

1. Is there any influence of the soil, as expressed in soil types, on moisture indication by vegetation, not taking into account the influence of the water table?
2. To what extent is there any agreement in moisture indication by means of soil- and vegetation-moisture classes?
3. Is there any way in which differences in vegetation, as expressed by the vegetation-moisture classes, can be explained by the soil types and soil-moisture classes as used in this soil survey?

2. Method

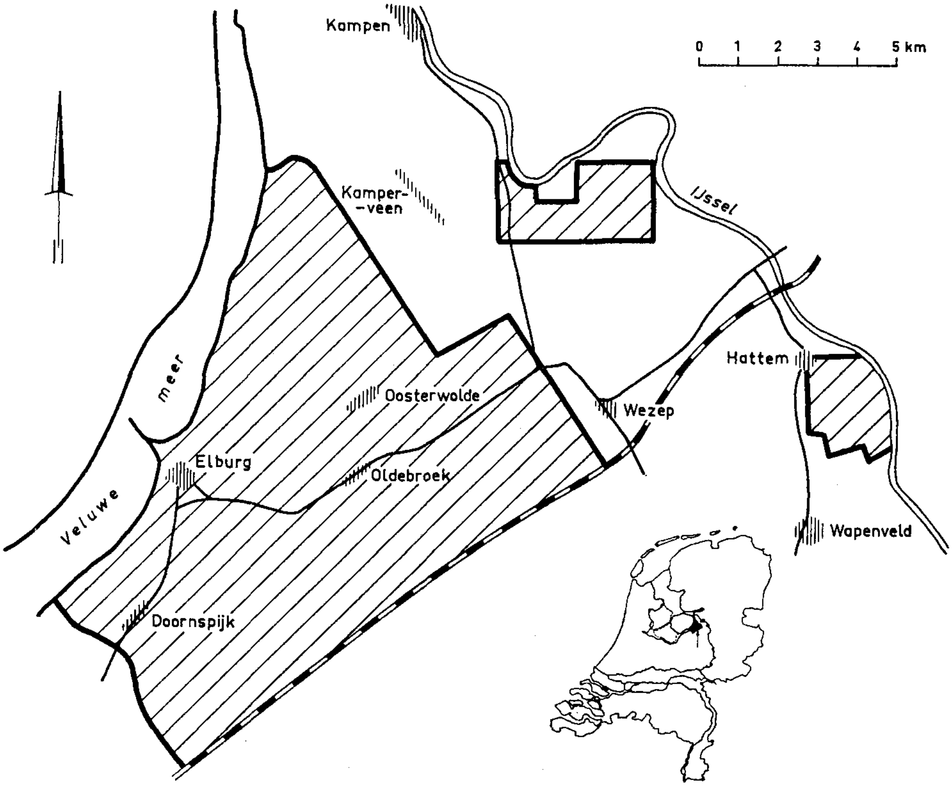
The comparison is carried out by a method developed by TH. A. DE BOER and used for measuring surfaces of different map-units.
The transparent soil map with soil types and soil-moisture classes is placed on top of the vegetation map with the vegetation-moisture classes. A transparent net of squares is placed on top of these two maps. Each square measures 0.25 ha, so that one point of intersection represents 0.25 ha.
The soil type, soil-moisture class and vegetation-moisture class coinciding at each intersection are recorded. The data thus obtained can be statistically treated.
An area of 6500 ha of grassland was investigated. Of this area 1300 ha is situated on sandy soils of which the soil-moisture class is given. The area investigated is shown in the FIGURE.

3. Classifications used

3.1. Vegetation

There are eight different vegetation-moisture classes, specified by letters and described in the following way: –

FIGURE. The area investigated; inset, map of the Netherlands on a much reduced scale (the arrow indicates the area investigated)



A. Over 40 % of drought indicators. Very dry grassland. Gross production often very low owing to growth depressions in summer;
B. 30—40 % of drought indicators. Dry grassland. Gross production fairly good in wet years, but growth depressions soon occur during dry periods in summer;
C. 15—30 % of drought indicators. Somewhat dry grassland. Gross production good in normal years; a slight chance of growth depressions in dry years. The sward does not often wither;
D. 0—15 % of drought indicators. Grassland with a normal water supply. Grass production good; in very dry years some growth depression; hardly any withering of sward;
E. 1—10 % of moisture indicators. Moist grassland; on an average grassland with the highest gross production, but in wet years losses due to puddling in spring and autumn;
F. 10—30 % of moisture indicators. Wet grassland; gross production in normal years fairly low owing to water surplus, in dry years fairly good; regular puddling;
G. 30—50 % of moisture indicators. Very wet grassland; gross production low as a result of almost continuous water surplus; impossible to pasture without puddling;
H. Over 50 % of moisture indicators. Marshland; hardly suitable for any grassland husbandry.

3.2. Soil

The soils are divided up into many soil types, indicated by a combination of figures, sometimes with the addition of a letter. The sandy soils are also divided up into soil-moisture classes, shown by Roman numerals affixed to the soil-type code (WESTERVELD, 1958). The soil types and soil-moisture classes referred to in this article have the following codes and significations: –

Deeply disturbed soils; silt content of the topsoil 15—60 %

Symbol	Depth of the peat (cm)
0.2	>80—<120 or absent
0.2 ij	>80—>120
0.5	50 to 80—>120

Moderately fine (f) and moderately coarse (c), not loamy, humous sandy soils

Symbol	Depth of humous layer (cm)	Profile below humous layer
1.51 (f)	<35	A/C prof.
1.52 (f)	<35	humus podzol
1.01 (f)	35—50	A/C prof.
1.02 (f)	35—50	humus podzol
1.5 (f)	50—80	various
1.73 (c)	<35	humus podzol
$1.\frac{2}{1}3$ (c/f)	35—50	humus podzol
1.23 (c)	35—50	humus podzol
1.2 (c)	>80	various

Additions: i = 5—10 % and j = 10—15 % silt in topsoil.

Peaty and peat soils with sandy subsoil

Symbol	Silt content of topsoil (%)	Depth of sand (cm)
3.1	<15	<50
3.5	>15	<50
3.4	<15	>50
3.3	>15	>50

Addition: e = artificially covered with sand.

Clayey sand soils with moderately fine sand

Symbol	Silt content of topsoil (%)	Depth of clayey topsoil (cm)
4.0	<15	<35
4.1	<15	35—60
4.2	15—25	<35
4.3	15—25	35—60
4.5	25—35/45	<35
4.6	25—35/45	35—60

Clay soils (c), peat covered with clay (cp) and sand covered with clay (cs)

Symbol		Depth of clay cover (cm)	Silt content in clay cover (%)		
			at the top	at the bottom	transition at (cm)
5.2	(cp)	25—50	30—45	30—45	—
5.3	(cp)	25—50	45—60	45—60	—
5.4	(cp)	25—50	45—65/70	45—65/70	—
5.5	(cp)	25—50	60—75	60—75	—
5.30	(cp)	25—50	45—60	60—75	15—35
5.50	(cp)	25—50	60—75	>75	15—35
6.30 + 7.30	(cp)	50—80	45—60	60—75	15—35
6.31 + 7.31	(cp)	50—80	45—60	60—75	35—50
8.05	(cs)	35—50	<15	<15	—

Continued on p. 10

Continued from p. 9

Symbol		Depth of clay cover (cm)	Silt content in clay cover (%)		
			at the top	at the bottom	transition at (cm)
8.0	(c)	>80	<15	<15	—
8.1	(c)	>80	15—30	15—30	—
8.5	(c)	>80	60—75	60—75	35—50
8.31	(c)	>80	45—60	60—75	50—80
8.33 + 9.33	(c)	>80	45—60	60—75	—

Additions : a = High forms of 8.0, 8.1 and 8.05.
x = Sand beginning between 80 and 120 and continuing below 120.
y = peat beginning between 80 and 120 and continuing below 120.

Soil-moisture class	Depth of gley phenomena below surface (cm)	Depth of total reduction below surface (cm)
I	>125	>125
II	100—125	>125
III	75—100	>125
IV	60— 75	>125
V	45— 60	ca. 125
VI	10— 45	80—100 to 125
VII	<10	<80

Approximate agricultural interpretation of the soil-moisture classes:

I and II : Only suitable for rye, potatoes and turnips; not very suitable to unsuitable for permanent pasture and ley farming;

III : Only suitable for rye, potatoes, turnips and oats; sometimes moderately suitable for beets; not very suitable to unsuitable for permanent pasture; moderately suitable for short-time leys;

IV : Suitable for rye, potatoes and oats; moderately suitable for beets; not very suitable for permanent pasture; moderately suitable for short-time leys;

V : The best soils for ley farming; suitable for beets; in winter sometimes too wet for winter crops; moderately suitable for permanent pasture; most suitable for long-term leys;

VI : Good grassland soils, seldom any withering; growth depressions on the higher parts in summer; too wet for winter crops; summer crops only on the drier parts;

VII : Mainly soils with very wet grasslands; heavy puddling; growth late in spring, terminating early in autumn; rather unsuitable for arable land.

4. Grassland vegetation on soil types without distinct soil-moisture classes

4.1. Introduction

We will first examine the influence of profile properties, except for the water table, on the moisture indication by vegetation.
The results of counting show the distribution of the vmc's [1] A—H in every soil type. In order to ascertain the influence of true soil properties on the distribution of the points over the vmc's, comparisons are made within small series of soil types, differing in one factor only, which may be assumed to influence the moisture supply. The soil types chosen were mainly those which occupy a fairly large area.

[1] For convenience sake the two moisture classes based on soil and vegetation are henceforward abbreviated smc and vmc.

A check of various points in the field showed that extreme, unexpected combinations of vmc's and smc's were caused by slight differences in the maps used, inevitable inaccuracies in plotting the limits in the field, and by similar errors insignificant in themselves. As a matter of fact, these errors also occur in the other combinations, but they are not obvious there. However, they have an unfavourable effect on the reliability. To provide some check on the reliability of the data, the numbers based on over 20 points counted are in bold type, *i.e.* according to the maps a combination with an area of over 5 ha. This limit is rather arbitrary, but the numbers actually counted can always be ascertained from the tables.

4.2. Comparison of soil types

The first factor selected is the silt content of the topsoil. TABLE 1 compares a few series of soil types differing in this factor only. The table shows changes in many

TABLE 1. Influence of silt content on moisture indication by vegetation

Soil type	Silt content (%)	Number of points	% surface area in vegetation-moisture class							
			A	B	C	D	E	F	G	H
Peaty soils										
3.1	<15	259	—	—	**9**	**39**	**43**	7	2	—
3.5	>15	539	—	—	+	**5**	**29**	**61**	**5**	—
Peat soils										
3.4	<15	908	—	—	+	**5**	**39**	**52**	**4**	—
3.3	>15	1020	—	—	+	**3**	**32**	**60**	**5**	—
Clayey sand soils										
4.1	<15	129	2	**21**	**48**	**26**	3	—	—	—
4.3	15—25	964	1	2	**17**	**39**	**34**	**7**	+	—
4.6	25—40	410	+	2	**11**	**27**	**50**	**10**	—	—
4.0	<15	77	14	**40**	**26**	**11**	8	1	—	—
4.2	15—25	402	+	1	**8**	**44**	**36**	**10**	+	—
4.5	25—40	261	—	+	6	**28**	**43**	**23**	+	—
Peat with a thin clay cover										
5.30	45—60 on 60—75	264	—	—	1	**12**	**78**	9	—	—
5.5	60—75	1367	+	+	1	**9**	**63**	**26**	1	—
5.50	60—75 on >75	68	—	—	—	3	**81**	13	—	3
5.2	30—45	309	—	—	1	3	**29**	**67**	—	—
5.3	45—60	1215	—	+	+	**2**	**23**	**69**	**6**	—
5.4	45—65 to 70	842	—	—	—	—	**4**	**94**	2	—
5.5	60—75	1367	+	+	1	**9**	**63**	**26**	1	—
Peat covered with clay										
8.0 ij	<15	14	—	14	7	57	22	—	—	—
8.1 ij	15—30	29	—	3	7	38	45	7	—	—
8.5 ij	60—75	23	—	—	—	9	61	27	3	—

cases, indicating that the moisture capacity increases with the silt content, as was anticipated. It seems, however, that the effect is not so clear or even absent at the higher silt contents. This is also true of peat soils. There is no essential difference between the two soil types.

The second factor is the height of the clay cover (TABLE 2). Only clayey sand soils yield sufficient data to enable a comparison to be drawn. TABLE 2 shows about the same effect as TABLE 1. Only types 4.0 and 4.1 change over to the wetter side as the height of the clay cover increases. The heavier types 4.2—4.6 show the reverse effect.

TABLE 2. Influence of depth of clay cover on moisture indication by vegetation

Soil type	Depth of clay cover (cm)	Number of points	% surface area in vegetation-moisture class							
			A	B	C	D	E	F	G	H
Clayey sand soils										
4.0	<35	77	14	**40**	26	11	8	1	—	—
4.1	35—60	129	2	**21**	**48**	**26**	3	—	—	—
4.2	<35	402	+	1	**8**	**44**	**36**	**10**	+	—
4.3	35—60	964	1	2	**17**	**39**	**34**	**7**	+	—
4.5	<35	261	—	+	6	**28**	**43**	**23**	+	—
4.6	35—60	410	+	2	**11**	**27**	**50**	**10**	—	—

TABLE 3. Influence of depth of peat on moisture indication by vegetation

Soil type	Depth of peat (cm)	Number of points	% surface area in vegetation-moisture class							
			A	B	C	D	E	F	G	H
Deeply disturbed soils										
0.2		114	1	5	13	**28**	**48**	5	—	—
0.2 ij	>80	123	1	—	1	16	**62**	**18**	2	—
0.5	50—80	69	—	—	—	10	9	**33**	**48**	—
Peat with clay cover										
8.31 ij, 8.33 ij, 9.33 ij	>80	64	3	1	8	27	14	**47**	—	—
6.30, 6.31, 7.30, 7.31	50—80	159	—	3	8	**26**	**49**	**14**	—	—
5.30	25—50	264	—	—	1	**12**	**78**	9	—	—

The influence of the depth of the peat subsoil could be studied on disturbed soils and clay-on-peat soils (TABLE 3). The disturbed soils clearly show an increased moisture indication the closer the peat is to the surface. This effect is absent from the clay-on-peat soils.

4.3. Discussion

These effects may be explained by the properties of the soil and by variation of the water table. In several other parts of the Netherlands the water table was found to be more important for the moisture indication by vegetation than other soil properties (DE BOER & PONS, 1960). This will be obvious when the distribution of vmc's is compared in certain soil types with and without addition a, referring to high forms of these soil types (TABLE 4). The differences between the high soil types and the analogous normal ones are considerable.

It will be interesting to see to what extent the soil-type series discussed above differ systematically in height, maybe causing a difference in the average water table. Recent geological history will yield some data concerning this problem.

Roughly, the area was formed as follows: -

On the sandy soils, sloping to the north and west, dating from the glacial period, peat was formed where the water table was sufficiently high. The peat therefore wedges out over the sandy soils.

TABLE 4. Influence of relative height on moisture indication by vegetation

Soil type	Number of points	% surface area in vegetation-moisture class							
		A	B	C	D	E	F	G	H
Clay soils									
8.0	152	2	2	**35**	**49**	12	—	—	—
8.0 a	46	**76**	13	9	2	—	—	—	—
8.05	122	—	2	**20**	**66**	11	1	—	—
8.05 a	35	**89**	—	6	3	—	2	—	—
8.1	184	1	+	8	**48**	**42**	1	—	—
8.1 a	64	**33**	31	23	13	—	—	—	—
8.1 x	33	—	24	21	46	9	—	—	—
8.1 ax	18	50	11	17	22	—	—	—	—

Clay originating from the "IJssel" and "Zuiderzee" was deposited on top of this, but only in places reached by its flood water. Moreover, the clay was not only deposited on the peat, but sometimes on the sandy soils as well. As sedimentation was further away from the "IJssel" or "Zuiderzee", the clay cover is thinner and the clay material heavier. Generally speaking, the ground is lower as the clay cover is thinner (so that the peat is higher in the profile) and the clay material heavier. In peat-on-sand soils, the soils with a shallow peat cover are somewhat higher than those with a high peat cover (WESTERVELD, 1958).

Although the landscape has only been described in a rough outline, it is evident that the differences between the soil types relating to the types of grassland occurring on them need not to be due to soil properties. But the influence of the height of the clay cover on the clayey sand soils with a low silt content cannot be explained by the above-mentioned characteristics of the landscape.

In order to decide to what extent the properties of the soil or the water table lead to the differences in distribution of vmc's, we will discuss the theoretical influence of both soil properties and water table on moisture indication by the vegetation.

Silt content, height of the clay cover and similar factors mainly act via the water capacity and the possibility of capillary rise.

The influence of these factors is mainly reflected in the tendency to water shortage. This tendency is indicated by the percentages of the vmc's A, B, C and D only. The vmc's E and F mainly depend on ground water, as will be shown in paragraph 7 and more or less indicate a water surplus. It is unlikely that the above-mentioned soil factors have a significant effect on the water surplus.

In view of these considerations it may be expected that the influence of the pure soil type will be reflected only in the percentages of the classes A, B, C and D, whereas the differences in the average water table will also be reflected in classes E, F and G.

In view of these facts, only the differences between the soil types 4.0 and 4.1 must be due to typical soil properties; but the differences between the types 4.0 and 4.2; 4.1 and 4.3; 0.2 and 0.2 ij; 8.0 ij and 8.1 ij, although explainable in another way, are probably also partly dependent on these properties. This is quite understandable as the silt content, height of the clay cover and depth of the peat subsoil will be more important on the very light clay and clayey sand soils than on soil types which already have a high moisture capacity.

5. Grassland vegetation and artificial covering with sand

A separate problem is the artificial covering of peat soils with sand. Soil type 3.4

is divided into the true type and the same profile artificially covered with sand to improve the bearing capacity (addition e).
A comparison (TABLE 5) shows that on sand-covered profiles vmc F is less frequent, whereas vmc E is in much greater evidence. This might indicate that the water economy was improved by sand covering. Experience has shown, however, that the bearing ca-

TABLE 5. Influence of artificial sand cover on moisture indication by vegetation

Soil type	Number of points	% surface area in vegetation-moisture class							
		A	B	C	D	E	F	G	H
Peat soils									
3.4	922	—	—	+	4	38	52	4	—
3.4 e	376	—	—	1	9	66	24	+	—

pacity of the soil is improved by sand covering, but not always the water supply, so that in many cases there is no change in the vmc.
Consideration of the location of the sand-covered areas shows that they are often situated in the transition areas from peat to sandy soils which are naturally higher.
Non-covered parts in sand-covered areas show no outstanding moisture indication.
Moreover, sand covering mainly took place in the neighbourhood of farms (WESTERVELD, 1958) which were no doubts built on the highest parts of these wet areas.
It would therefore seem probable that in most cases the sand-covered fields were also drier before they were covered.

6. Grassland vegetation on soil types subdivided into soil-moisture classes

6.1. Effect of relative height

Discussion of the sandy soils has been deliberately postponed until now. These soil types are subdivided into moisture classes. In this case, too, several types of sandy soil may be compared in the same manner as above. However, in this instance the effect of relative height is more or less limited by selecting points belonging to a single moisture class. TABLE 6 demonstrates the effect which subdivision of soil types into soil-moisture classes has on the distribution of points over the vegetation-moisture classes. To prevent the number of points being too few smc's I—IV were combined. It will be clear that the distribution range is only slightly reduced. There are, however, fairly distinct differences in the distribution of the points over the vmc's. The trend of the changes is according to expectation.

6.2. Effect of typical soil factors

TABLE 7, which represents the effect of subdividing into soil types the points belonging to one smc, shows a less obvious effect.
Within the classes I—IV a distinction is made between soil types in fairly coarse, non-loamy sands and those in moderately fine-textured sands. Although the distribution over the smc's I—IV is not quite the same, the types in coarse sands denote drier conditions than those in finer sands.
Within the smc's V, VI and VII the soil types occurring most frequently are arranged according to the height of the humous layer. In this case the differences between the soil types are slight and the range of distribution is hardly reduced. There is an indication, however, that soil type 1.52, which relates to humus podzols, is somewhat wetter and soil type 1.51, which relates to gley soils, is somewhat drier than the

TABLE 6. Effect of subdivision into soil-moisture classes on moisture indication by vegetation

Soil type	Soil m.c.	Number of points	% surface area in vegetation-moisture class							
			A	B	C	D	E	F	G	H
Humous sandy soils										
1.51	total	138	10	14	**29**	**29**	**17**	1	—	—
	I—IV	—	—	—	—	—	—	—	—	—
	V	8	62	38	—	—	—	—	—	—
	VI	103	8	16	**39**	**27**	10	1	—	—
	VII	27	—	—	—	44	52	4	—	—
1.52	total	182	1	2	**18**	**47**	**20**	**12**	—	—
	I—IV	1	—	—	—	100	—	—	—	—
	V	55	2	6	36	**51**	5	—	—	—
	VI	110	—	1	9	**43**	**30**	**19**	—	—
	VII	16	—	—	12	63	13	12	—	—
1.01	total	906	1	**6**	**43**	**41**	**8**	+	—	—
	I—IV	—	—	—	—	—	—	—	—	—
	V	55	—	14	**60**	22	4	—	—	—
	VI	768	1	**6**	**45**	**39**	**9**	+	—	—
	VII	83	—	**1**	19	**70**	10	—	—	—
1.02	total	587	**5**	**19**	**31**	**32**	**11**	2	—	—
	I—IV	51	16	**55**	17	10	2	—	—	—
	V	283	7	**23**	**38**	**27**	4	1	—	—
	VI	248	1	7	**27**	**42**	**21**	2	—	—
	VII	5	20	—	—	40	20	20	—	—
1.5	total	632	**12**	**24**	**38**	**15**	**10**	1	—	—
	I—IV	147	**20**	**33**	**34**	10	2	—	—	—
	V	304	**12**	**30**	**42**	**14**	2	—	—	—
	VI	165	5	7	**37**	**18**	**29**	4	—	—
	VII	16	—	—	—	50	50	—	—	—

moisture class as a whole. A similar difference between types 1.01 and 1.02, which also relate to gley soils and humus podzols respectively, was difficult to demonstrate. Furthermore, the average indication of the vegetation on soil type 1.5 in smc V is drier than that of the other types, although it has the highest humous layer. It was not possible to ascertain whether the height of the humous layer had any further effect.

The additions i and j, which relate to the silt content of the topsoil, will be used in another attempt to discover whether typical soil properties have any effect. These comparisons concern smc VI only as this class was most in evidence. It may, in fact, be expected that the effect of a higher silt content will be more clearly reflected on drier soils, but the occurrence of any silt content is closely associated with the lower soils of the classes VI and VII. It is possibly owing to this fact that TABLE 8 only shows a slight and indistinct effect of silt content on the vegetation indication.

The only fact to be established is that except for soil type 1.01, vmc-A is limited to the soil types with a low silt content, but the number of points concerned is very small.

When vmc's D and C occur on the drier soils of the smc's I—V, they may be expected to be more or less limited (at least in proportion to the vmc's A and B) to the soil types with a higher moisture capacity. These are the soils with a certain silt or humus content in the topsoil. However, only the contrary might be established.

TABLE 7. Influence on moisture indication by vegetation of texture and depth of humous layer with several soil-moisture classes

Soil m.c.	Texture and depth of humous layer (cm)	Soil type	Number of points	% surface area in vegetation-moisture class							
				A	B	C	D	E	F	G	H
Humous sandy soils											
I—IV	coarse	1.$^{2}_{1}$3 + 1.23									
	fine	1.2 + 1.73	68	76	15	9	—	—	—	—	—
	fine	1.02	51	16	55	17	10	2	—	—	—
		1.5	147	20	33	34	10	2	—	—	—
V		total	705	9	24	47	23	3	+	—	—
	<35	1.51	8	62	38	—	—	—	—	—	—
	<35	1.52	55	2	6	36	51	5	—	—	—
	35—50	1.01	55	—	14	60	22	4	—	—	—
	35—50	1.02	283	7	23	38	27	4	1	—	—
	50—80	1.5	304	12	30	42	14	2	—	—	—
VI		total	1394	2	7	37	36	15	3	—	—
	<35	1.51	103	8	16	39	27	10	1	—	—
	<35	1.52	110	—	1	9	43	30	19	—	—
	35—50	1.01	768	1	6	45	39	9	+	—	—
	35—50	1.02	248	1	7	27	42	21	2	—	—
	50—80	1.5	165	5	7	37	18	29	4	—	—
VII		total	147	1	1	12	61	22	3	—	—
	<35	1.51	27	—	—	—	44	52	4	—	—
	<35	1.52	16	—	—	12	63	13	12	—	—
	35—50	1.01	83	—	1	19	70	10	—	—	—
	35—50	1.02	5	20	—	—	40	20	20	—	—
	50—80	1.5	16	—	—	—	50	50	—	—	—

TABLE 8. Influence on moisture indication by vegetation of silt content and depth of humous layer

Soil type	Soil m.c.	Silt content (%)	Number of points	% surface area in vegetation-moisture class							
				A	B	C	D	E	F	G	H
Humous sandy soils											
1.51	VI	0— 5	103	8	16	39	27	10	1	—	—
1.51	VI i	5—10	88	—	1	8	77	14	—	—	—
1.51	VI j	10—15	11	—	—	30	46	15	8	—	—
1.52	VI	0— 5	110	—	1	9	43	30	17	—	—
1.52	VI i	5—10	57	—	5	42	37	16	—	—	—
1.52	VI j	10—15	39	—	—	13	54	28	5	—	—
1.01	VI	0— 5	768	1	6	45	39	9	+	—	—
1.01	VI i	5—10	514	3	15	35	28	16	2	1	—
1.01	VI j	10—15	103	2	5	24	36	33	—	—	—
1.02	VI	0— 5	248	1	7	27	42	21	2	—	—
1.02	VI i	5—10	330	—	2	13	55	29	1	—	—
1.02	VI j	10—15	113	—	3	18	45	34	—	—	—
1.5	VI	0— 5	165	5	7	37	18	29	4	—	—
1.5	VI i	5—10	101	—	8	25	39	27	1	—	—
1.5	VI j	10—15	60	—	15	33	33	19	—	—	—

It is therefore evident that on sandy soils the water table represented by the smc's has more influence on the moisture indication by vegetation than the typical soil properties. It could not be shown that the height of the humous layer and of the silt content of the topsoil had any distinct effect. Soil types in moderately coarse sands are the only ones that are usually drier than those on finer sands in the same soil-moisture class.

7. Relation between soil-moisture class and vegetation-moisture class

7.1. Introduction and results of counting

Although the soil-moisture classes should not be considered in isolation from the soil type, it is tempting to examine to what extent the vmc's and smc's show the same result in indicating the moisture properties of the soil.
Although both methods of classification aim at indicating moisture properties, the two classes do not indicate quite the same complex of properties.
The smc's are mainly based on ground-water characteristics in the soil and are actually intended to indicate the water table. The vegetation, however, responds to the entire complex of soil properties that determines the water supply to the roots. The water table is also a part of this complex, but factors independent of ground water also influence the water supply to the plant roots. These factors are reflected as far as possible in the soil types, but the microrelief, the state of the trenches and unknown or elusive factors may also play a part.
Hence the relation will not be so close that plots with a certain vmc will only occur on soils belonging to one or two smc's. Other reasons for the diversity in the results of the two survey methods are to be found in the inaccuracies inherent in the method.
TABLE 9 shows the results of the count with respect to the combination smc - vmc. There is a difference in the total number of points counted per smc. The distribution of vmc's is therefore also shown proportionally.

TABLE 9. Actual and proportional number of coincidences of vegetation-moisture classes with soil-moisture classes

Vegetation-moisture class	Soil-moisture class															
	I		II		III		IV		V		VI		VII		Total	
		%		%		%		%		%		%		%		%
A	14	100	14	70	53	49	27	16	71	9	66	2	1	+	246	5
B	—	—	5	25	26	24	64	38	188	23	244	7	15	2	542	10
C	—	—	1	5	19	18	51	30	354	43	982	30	77	9	1484	28
D	—	—	—	—	10	9	23	14	171	21	1343	41	372	43	1919	36
E	—	—	—	—	—	—	3	2	26	3	598	18	325	37	952	18
F + G	—	—	—	—	—	—	1	1	6	1	64	2	79	9	150	3
Total	14		20		108		169		816		3297		869		5293	

7.2. Discussion

The vegetation's moisture supply is always determined by the water table and other habitat factors together. It is known, however, that a higher or lower water table can be more or less compensated by other habitat factors influencing the moisture economy of the soil. The more the water table deviates from a certain level preferred by some vmc, the more extreme must be the other habitat factors for the same vmc to occur.

So, in order to evaluate the figures of TABLE 9 we must ascertain to what extent the smc's are correlated with habitat factors influencing moisture supply. This is only possible by means of the smc-soil type combination represented in TABLE 10.

TABLE 10. Proportional distribution of soil types over the soil-moisture classes

Soil type	Number of points	Soil-moisture class						
		I	II	III	IV	V	VI	VII
1.01	2211	—	—	—	—	7	44	60
1.02	1096	—	5	8	25	36	23	4
1.11	130	—	—	—	—	+	1	9
1.5	834	7	10	46	59	40	11	2
1.51	375	—	—	—	2	3	7	15
1.52	324	—	—	1	—	7	7	3
1.$\frac{2}{1}$3 + 1.23 + .12 + 1.73	79	93	80	32	4	1	—	—
Remainder	244	—	5	14	10	6	6	7
Total number of points	5293	14	20	108	169	816	3297	869

TABLE 7 shows that only soil types on moderately coarse sand have a deviating moisture indication. As the smc's I, II and III are largely associated with these soil types, the mean vegetation indication of these smc's will be too dry, in the sense that the figures for vmc A will generally be too high and those for the vmc's B and C too low.

Apart from that, the percentages in which the vmc's occur in the different smc's can be taken as an index of their preference for the ground-water conditions indicated by these smc's.

Inspection of the figures in TABLE 9 shows a clear decrease in the percentage of very dry grassland (A), going from class I to VII. Vmc B covers a quarter of classes II, III and V, has its optimum in class IV, and is absent in class I, probably owing to the deviating soil types in this class. Somewhat dry grassland (C) is proportionally most frequent in class V, but it is also present to a fairly considerable extent in classes IV and VI. Grassland with a normal water supply (D) occurs most frequently in classes VI and VII, class VI with vmc C being second, vmc E covering about the same area in class VII. Moist and wet grasslands have their optimum in class VII.

Vmc A, although having its optimum in class I, also occupies a greater part of the smc's II—V. On the other hand vmc F, and to a lesser extent vmc E, is mostly limited to smc VII. The vmc's B, C and D frequently occur in four smc's as well.

Obviously the water table has much more significance for the vegetation in the classes VII and VI than on the sites of classes I—V. The vmc's F and E are closely associated with a high water table, agreeing with the observation that the moisture indicators more or less indicate a surplus of water.

Although vmc F is mainly limited to smc VII, it only covers a fairly small part of this class. This vmc probably has its optimum at higher water tables than those actually occurring in smc VII. Soils with these high water tables will be mainly peaty, in which case they do not come under the sandy soils counted. The TABLES 1, 3 and 5 bear out this assumption.

In any case, the agricultural description of smc VII as being mainly too wet for good grassland is not true of the sandy soils.

We may conclude that there is a clear, although not close correlation between the two methods of indicating moisture conditions in grassland. The actual correlation between vegetation-moisture class and soil-moisture class in the area investigated passes from the combination A/I, via B/IV and C/V to D-E/VII.
The vmc's E and F are more closely related to smc VII than are the vmc's A and B to classes I and IV.
Vmc F has its optimum at higher water tables than those generally occurring in sandy soils.

8. Vegetation as a result of soil and ground water

In several other areas in the Netherlands, where elaborate water-table measurements enabled a comparison to be made with vegetation, it was found that the water table could not altogether explain the vegetation-moisture classes observed, although the correlation may be rather distinct (DE BOER, 1954; DE BOER & PONS, 1960). In view of the results of the investigations discussed here it is not to be expected that a more satisfactory explanation can be obtained by combining data on the water table with data on soil properties as used. Even the points belonging to one soil type and one smc usually show a distribution over three or more vmc's. The better correlations are found on soil types with a high water table.
Further research is required into the factors causing the remaining differences in the vegetation.

9. Conclusion

Both the soil scientist and the botanist, although working in different ways, attempt to find the best method of characterizing the moisture conditions in the environment. The soil scientist has the advantage that he can investigate several soil properties by means of an established method. He is able to express these properties in figures. But the difficulty is to find the methods that exactly indicate the actual properties of the soil to which the plant responds, and which can be applied on a fairly large scale.
The botanist considers the botanical composition of the sward, indicating the habitat as a whole, and can describe similarities and differences in the environment as seen from the plant. But when these differences require some further interpretation he will sometimes fail to find an answer.
Obviously, the methods should be complementary. In order to find satisfactory solutions to practical and scientific problems combined pedological and phytosociological research is needed (ZONNEVELD, 1957).

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