Agricultural and pedological indication of grassland-vegetation survey units

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1. Introduction

The object of grassland surveying is to ascertain the use-value of the grassland by means of the vegetation and to reduce it to map form. At the same time it is hoped to gain an insight into the entire complex of environmental factors determining the yield and quality of the grassland.

DE BOER (1956) has compiled a number of survey units for Netherlands grasslands. These units are mainly inferred from the dry-weight percentages of certain grasses and herbs since Netherlands grassland cannot be adequately typified by the sole use of the combination of groups of environment indicators. An attempt was made to draw up a classification in which the effect of four groups of factors would be mainly reflected, viz. moisture-supply status, fertilisation status, form of use, and calcium status.

The vegetation units were compiled by starting from data already available on the reaction of the grassland plant species to various growing conditions, on the competitive capacity, etc.; this was made possible by the work of DE VRIES and his co-workers (DE VRIES and DE BOER, 1959). The value and significance of the vegetation units have to be empirically tested and ascertained at a later stage. If we assume that the units employed do, in fact, give a proper picture of the growing conditions, we may expect there to be a correlation between survey units and factors typifying moisture supply, fertilisation status, use-value and calcium status. We may also expect a certain relationship between vegetation units and grassland quality on the one hand and yield on the other.

Soil fertility research work undertaken by the Institute for Soil Fertility in the Gelderse Vallei from 1951 to 1953 and the Friese Wouden from 1955 to 1957 enabled such a test to be made.

2. Short description of the vegetation survey units

The classification of the grassland into vegetation survey units is based on groups of plant species exhibiting the same reaction with respect to a particular growth factor or a particular complex of growth factors. The amount of information supplied by these groups of plant species on the environmental factors concerned depends on the percentage by weight with which a number of plant species in the group concerned occur together.

We first consider the classification of the grassland with reference to the percentage by weight of the group of plant species providing information on the moisture-supply

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status. By moisture-supply status in this connection we mean the average moisture-supply status during a great number of growing seasons as reflected in the composiion of the grassland vegetation during fairly regularly recurring periods of moisture excess or deficit.

In the research area the plant species belonging to the drought indicator group and typifying the vegetation units A to C were mainly the following: *Poa pratensis, Agrostis tenuis, Achillea millifolium* and *Festuca rubra. Luzula campestris* spp. *vulgaris* and *Geranium molle* occurred less frequently. Depending on other factors than the moisture supply we find different proportions and combinations of these species. Thus on drought-sensitive grassland properly fertilised and used we find a considerable proportion of *Poa pratensis* whereas the said *Luzula* species does not occur. On poorly fertilised grassland *Festuca rubra* and *Agrostis tenuis* are chiefly in evidence, the said *Luzula* species and *Geranium molle* being mostly found. TABLE 1 shows the limits between which are situated the weight percentage of the drought indicator group for the corresponding vegetation units A to C.

TABLE 1. Vegetation units relating to the moisture-supply status.

Vegetation unit	Percentage of drought or humidity indicators	Designation of the moisture -supply status
A	over 40 % of drought indicators	very dry
B	31—40 % of drought indicators	dry
C	15—30 % of drought indicators	somewhat dry
D	less than 15 % of drought indicators	adequate supply of moisture
E	1—10 % of humidity indicators	humid
F	11—30 % of humidity indicators	wet
G	31—40 % of humidity indicators	very wet
H	over 40 % of humidity indicators	marshy

Vegetation units E to H typify the grasslands in which there may be said to be an increasing degree of excess moisture, at any rate during weather conditions which may give rise to this.

The group of plant species on which these vegetation units are based are known as humidity indicators. In the Friese Wouden these were *Alopecurus geniculatus* and *Ranunculus repens; Glyceria fluitans* and *maxima* were less general but still found in substantial amounts in the fields in question. *Phalaris arundinacea,* a few *Carex* species, *Eleocharis palustris, Polygonum amphibium, Lychnis Flos-cuculi* and *Mentha aquatica* were also occasionally encountered in the humidity indicator group.

What was said in connection with the drought indicators applies equally well to the proportions and combinations of the humidity indicator group. TABLE 1 shows the weight percentages of the humidity indicator group for the corresponding vegetation units.

Vegetation unit D comprises grassland having a moisture-supply status which we have termed adequate. On such grassland we find less than 15 % of drought indicators and scarcely any humidity indicators.

It occasionally happens that a grassland vegetation which according to, say, 35 % of drought indicators, should be classified as vegetation unit B, also contains a certain percentage of humidity indicators. This we term a vegetation that indicates an abnormal fluctuation in moisture supply at the said moisture status. We show this by adding an o to the code letters, e.g. Bo in the example given.

Both a humidity classification and a classification of the management status of the grassland can be compiled from the percentage of the group of plant species indicating good use and adequate fertilisation, and the group of plant varieties which point to bad use and a poor fertilisation status. The term "management status" requires further elucidation. All three factors of fertilisation, use and cultivation of grassland have an effect on its botanical composition. These measures are frequently carried out in conjunction and partly have the same effect on the botanical composition, so that they may also partly offset each other. As a result these measures have been combined in the comprehensive term "management".

Lolium perenne, Festuca pratensis, Phleum pratense, Poa pratensis, Poa trivialis and *Trifolium repens* belong to the group of plant species (indicators) which denote a good management status.

The group of indicators denoting a poor management status includes such species as *Anthoxanthum odoratum, Agrostis canina* and *Festuca rubra.*

TABLE 2 shows the limits between which the percentage of the said indicators should be situated. In this case also the percentage should denote the sum total of the indicator group concerned, but the combinations and proportions of the plant species may vary, for instance according to the moisture-supply status.

TABLE 2. Vegetation units relating to the management status.

Vegetation unit	Percentages of relevant indicators	Designation of the management status
I	over 60 % of indicators of good management status	good
II	45—60 % of indicators of good management status	adequate
III	less than 45 % of indicators of good management status	moderate
IV	over 10 % of indicators of poor management status	inadequate to poor

3. Method followed

The average fertilisation status, moisture supply, yield, etc. was calculated of each vegetation unit. In all cases the corresponding standard deviation was ascertained in addition to the average. Owing to the qualitative nature of the vegetation unit the usual correlation computation cannot be employed.

It is to be expected that the assumed relationship between vegetation units and fertilisation status, for example, will not be complete. Owing to various causes there is a spread in values within a single vegetation unit, so that the average is regarded as the best estimate of yield, water table, etc. belonging to any given vegetation unit. The accuracy of this average depends both on the size of the variance within a single vegetation unit and the number of data from which the average is calculated. The statistical significancy of the differences between the units is invariably calculated. This degree of reliability wil obviously depend on the magnitude of the difference, on the variance within the units and on the number of data employed.

The difference between two extreme vegetation units is comparatively easy to demonstrate, but it is far more difficult to ascertain the reliability of a difference in properties beween two vegetation units which do not differ vary greatly, particularly when there are few data available. The impossibility of demonstrating the reliability of a difference is no proof that the assumption made about the relationship is incorrect, — it may also be due to the lack of data. One way out of the difficulty is to make a simultaneous assessment of a greater number of differences and to determine whether the relationship anticipated does in fact exist.

Before the statistical significancy was examined by means of the known t-test, the F test was invariably employed in order to ascertain whether the variances in the vegetation units differed in magnitude in a statistically reliable manner. If this proved to be the case (criterion: significance level 1 %) the t-test was subsequently applied. From the agricultural point of view also it may be important to recognise these variance differences. Generally speaking, however, there are no great differences.

The great drawback attaching to this method is that owing to the existence of correlations between, for example, the soil properties, the causal factors cannot be sufficiently indicated. A vegetation unit is the result of a great number of factors, so that the individual effect and significance of the factors is often difficult to determine. Consequently the comparatively large amount of material provided by some 230 experimental plots does not afford sufficient possibilities for a partial classification. On the other hand in special cases it is often still possible to adduce a causal effect by using our knowledge of the reaction of the individual plant species. This can be clearly seen, for example, in the relationship between vegetation units and water table.

The description of the vegetation units has already shown that they can classified in two ways, viz. according to the moisture supply and according to management. In the Gelderse Vallei and the Friese Wouden correlations exist between both classifications, since units of good quality and management are found on fields which have a good supply of moisture, etc. But these correlations between the two classifications do not usually occasion any great difficulty of interpretation.

The results of the work will be demonstrated by means of a few examples. For this purpose we have only taken examples from the second investigation, the results of the first investigation having already been published elsewhere (DE BOER and FERRARI, 1956). Actually both investigations gave approximately the same results. We shall only discuss the relationships between vegetation units and yield, moisture supply, soil fertility factors and a number of management factors.

4. Vegetation unit and yield

The first question that arises is whether the vegetation units can provide us with some information on the yield of the grassland concerned. TABLE 3 is an example of a relationship between the vegetation units and the average yields in 1955. The moisture supply was taken as the classification criterion. The yields were determined by means of visual estimates (FERRARI, 1953).

If first of all we inspect the average yields of the various vegetation units we can see that there is a distinct relationship. This relationship corresponds to the ascertained effect of the depth of the water table below the surface and the yield found by means of a regression analysis in the same material. There is a range of

TABLE 3. Average yield in 1955 in the Friese Wouden of the vegetation units arranged according to their indication of increasing moisture supply. In this and subsequent tables the symbols +, ++ and +++ always denote the statistical significancy of the difference at the 5 %, 1 % and 0,1 % level respectively. Cf. TABLE 9 for the number of data.

Vegetation unit	A	B	C	D	E	F	G	H	Vegetation unit
Average yield of dry matter in q/ha	108	114	119	125	128	104	81	74	
			+	+++	+++		+++	+++	A
			+++	++	+++	+	+++	+++	B
						++	+++	+++	C
						+++	+++	+++	D
						+++	+++	+++	E
							+++	++	F
									G

approximately the maximum yields, whereas the extremely dry and wet vegetation units show a distinctly lower yield. This relationship was found in all six experimental years.

Generally speaking the steepest decline in yield occurs in the wet vegetation units. The yield of units G and H is far below that of the very-dry variant. It is obvious, therefore, that the pattern may be somewhat modified in years drier than the experimental years. The highest yields in q of dry matter per ha (obtained by mowing) are obtained in units D and E. Whether these also give the highest farming results is another matter. Such results are probably obtained by less puddling on the somewhat drier variant (D and C).

The differences in yield are usually very statistically significant, but it will be clear that owing to the character of an optimum curve it is difficult or impossible to show the differences in yield between A and F, however extreme they may be.

As TABLE 4 shows, there is also a clear connection between management and yield. In this case the vegetation units are arranged according to a decreasing indication of management.

TABLE 4. The average yield of the vegetation units in 1955 classified according to their indication of decreasing management. Cf. TABLE 8 for the number of data.

Vegetation unit	I	II	III	IV	V	Vegetation unit
Average yield of dry matter in q/ha	136	127	110	102	85	
		+++	+++	+++	+++	I
			+++	+++	+++	II
			+	+	+++	III
					++	IV

This classification also reveals a clear correlation between vegetation unit and yield. The best unit from the point of view of botanical composition does in fact give the best yield. The yield of units assessed as poor is still greatly inferior. The differences in yield, nearly all of which are statistically very significant, may differ extensively and are of an order of magnitude which is the same as that obtained in the classi-

fication according to moisture supply. These differences were also found in the Gelderse Vallei.
The relationship shown in TABLE 4 is valid for an average moisture supply. Inspection of the data relating to various moisture statuses shows that this relationship is a general one.

5. Vegetation unit and moisture supply

It may be asked whether the hypothetical classification of the vegetation units according to moisture indication, viz. the series A to H, is actually a classification according to moisture supply. Disregarding small differences in rainfall (the experimental plots were scattered over a small area) it can be assumed that differences in moisture supply are determined by the height of the water table and the moisture-retaining capacity of the profile. In the first place, therefore, we should expect a clear correlation between the classification of the vegetation units according to moisture supply and the height of the water table (the water table is an important production factor in Holland). Such a relationship is in fact found to exist.
TABLE 5 shows that there is a clear correlation between these vegetation units and the height of the water table. The dry variants have a deep water table and the wet variants a high one. Most differences in average water table are statistically very significant. Differences in moisture-retaining capacity may obviously have an effect in addition to the depth of the water table. Unlike the situation in the Gelderse Vallei,

TABLE 5. The average summer water table over the years 1955, 1956 and 1957 of the vegetation units classified according to their indication of increasing moisture supply.

Vegetation unit	A	B	C	D	E	F	G	H	Vegetation unit
Average water table in cm below surface	160	125	119	93	77	50	42	34	
		++	+++	+++	+++	+++	+++	+++	A
				+++	+++	+++	+++	+++	B
				+++	+++	+++	+++	+++	C
					+++	+++	+++	+++	D
						+++	+++	+++	E
							+	+	F
									G

it was found however that in the Friese Wouden this factor was unimportant for the classification according to moisture supply (DE BOER and FERRARI, 1956). Exceptions were the wet peat soils which invariably had the wettest vegetation units. It would almost seem that in the Friese Wouden the effect of the profile has been more or less eliminated by the water table. It is also noticeable that the classification according to moisture indication cannot be correlated to the depth of boulder clay.
It was also ascertained to what extent the size of the water table fluctuations go together with the indication of an irregular moisture supply in the vegetation. TABLE 6 shows the average water tables (from February to November) over the years 1955 to 1957, the plots being classified according to the presence or absence of vegetation indicating an irregular supply of moisture.

TABLE 6. Relationship between indication of irregular supply of moisture in the vegetation units and the average water table from February to November over the years 1955, 1956 and 1957[1].

Vegetation unit	B	Bo	C	Co	D	E	Eo	F	Fo	Vegetation unit
Average water table in cm below surface	143	114	132	93	105	77	92	47	72	
		++		+++	+++	+++	+++	+++	+++	B
						+++	+	+++	++	Bo
				+++	+++	+++	+++	+++	+++	C
								+++		Co
						+++	+++	+++	++	D
							+++	+++		E
								+++		Eo
									+	F

[1] Differences in water table from those shown in *table* 5 are due to the fact that in connection with the criterion of irregular moisture supply certain plots are classified under other units.

This table shows that among the dry vegetation units B and C, the vegetations indicating an irragular moisture supply (Bo and Co) always have a higher average water table. In the humid vegetations E and F the position is reversed. As can be seen from TABLE 6, the differences between the average water tables of the said pairs of irregularly humid and not irregularly humid vegetations in the same humidity class are all statistically significant. From this it follows that a certain percentage of divergent humidity indicators in a given humidity class, at least in the soil profiles studied, are due to differences in the trend of the water tables. Without further investigation it is impossible to ascertain whether this is due to a difference in level or a difference in fluctuation of the water table. For this reason we also studied the relationship of the water table fluctuation to the presence or absence of an indication of an irregular moisture supply in the vegetation (TABLE 7). The fluctuation was assumed to be the difference between the highest and lowest water table.

TABLE 7. Relationship between indication of an irregular moisture supply of the vegetation units and extent of the fluctuation, averaged over the years 1955, 1956 and 1957.

Vegetation unit	B	Bo	C	Co	D	E	Eo	F	Fo	Vegetation unit
Average fluctuation	99	105	106	106	106	96	101	64	89	
					+			+++		B
								+++		Bo
						++		+++		C
								+++		Co
						++		+++		D
								+++		E
								+++		Eo
										F

The conclusion must be that there is either no difference in fluctuation (C and Co) or only slight differences. There is only a substantial difference in units F and Fo, and this is particularly important in that the water table is fairly shallow. From this we might possibly infer that it is only in a wet vegetation (humidity class F) that an irregularly humid indication of the vegetation is due to a substantial difference in fluctuation, viz. in the sense that in periods of drought the water table is considerably lower in this instance than in fields with a normal "wet" vegetation. In view of the results in TABLE 6, we must therefore consider there to be differences in the level of the water table in the other humidity classes.

6. Vegetation unit, soil fertility and management

Management is based on a great number of factors such as the form of use, fertilisation with nitrogen, phosphate, potash, etc. We may therefore expect the relationship between the classification for management indication and fertilisation and fertilisation statuses to be less distinct. This was the case in the Gelderse Vallei, and is possibly the case to an even greater extent in the Friese Wouden. TABLE 8 summarises the relationship between the vegetation units classified according to management indication and different factors.

TABLE 8. Relationship between vegetation units classified according to indication of management and average pH, potash, phosphate and magnesium status, average nitrogen, potash and phosphate fertilisation, and distance from field to farmstead.

Vegetation unit	I	II	III	IV	V
Av. pH-KCl	5,2	5,2	5,3	5,1	4,9
Av. potash status	34	28	24	21	17
Av. phosphate status	46	50	62	56	55
Av. magnesium status	165	167	168	162	124
Av. nitrogen fertilisation in kg/ha	155	168	164	131	114
Av. potash fertilisation in kg/ha	128	150	151	133	109
Av. phosphate fertilisation in kg/ha	42	54	51	47	41
Distance from farmstead in 100 m	29	42	98	86	115
Number of fields	44	71	54	49	13

This table shows a remarkable resemblance to the one relating to the vegetation units in the Gelderse Vallei. In the Friese Wouden as well the relationship between the classification made and the various properties is not very clear, and in addition the differences are not usually statistically significant. There is no clear effect of the pH. As expected, the only relationship is that between classification and potash status. Moreover soils with a fairly well managed sward have the highest fertilisation status; it is only the extremely poor variants that have a distinctly lower fertilisation status. The nitrogen, phosphate and potash fertilisations are in agreement with these findings; the moderate variants have the highest degree of fertilisation. Generally speaking grasslands with the best sward are those nearest the farmstead.
These figures are also interesting in connection with the humidity indication (TABLE 9). The wet variants are characterised by their great distance from the farmstead, a slightly higher pH, a low potash status and a relatively high phosphate and a high magnesium status. It is clear that the farmers apply a relatively large amount of fer-

TABLE 9. Relationship between vegetation units, classified according to indication of increasing moisture supply and average pH, potash, phosphate and magnesium status, average nitrogen, potash and phosphate fertilisation, and distance from field to farmstead.

Vegetation unit	A	B	C	D	E	F	G	H
Av. pH-KCl	5,1	5,0	5,0	5,1	5,3	5,7	5,5	5,8
Av. potash status	26	27	27	28	26	23	16	15
Av. phosphate status	53	51	45	45	51	81	88	107
Av. magnesium status	113	130	147	162	188	224	216	188
Av. nitrogen fertilisation in kg/kg	188	155	169	150	152	135	104	95
Av. potash fertilisation in kg/ha	177	143	162	135	127	123	111	88
Av. phosphate fertilisation in kg/ha	56	52	46	46	52	47	42	32
Distance from farmstead in 100 m	48	48	60	51	49	93	217	347
Number of fields	25	32	36	69	42	18	14	4

tiliser to the dry fields. Either it is considered a waste of money to fertilise wet fields or that additional fertiliser will promote growth in dry fields.
It is obvious from TABLES 8 and 9 that the classification according to indication of management has little or no connection with the factors investigated. It should be remembered that this classification is more concerned with the form of use, the quality of the sward and factors influencing this quality. But most factors in the tables have little to do with this.
The highest use-value need not be in variants D or E, and it may be questioned whether such grasslands are not too soft for use as pasture, especially in periods of somewhat greater precipitation. PIETERS attempted to form an estimate of the differences in susceptibility to puddling by a field method in which this susceptibility was assessed by means of puddles (PIETERS, 1961). The susceptibility is expressed in figures varying from 0 to 10. The sensitivity to puddling is shown in TABLE 10.

TABLE 10. The average sensitivity to puddling of the vegetation units classified according to their indication of increasing moisture supply.

Vegetation unit	A	B	C	D	E	F	G	H	Vegetation unit
Average sensitivity to puddling	1,0	2,0	3,3	4,7	5,7	7,7	8,2	8,3	
		++	+++	+++	+++	+++	+++	+++	A
			++	+++	+++	+++	+++	+++	B
				+++	+++	+++	+++	+++	C
					+	+++	+++	+++	D
						+++	+++	+++	E
									F
									G

It can be seen that there is a greater susceptibility to puddling as the moisture indication increases. It is noticeable that most differences are statistically significant. From this it follows that the spread within one variant is relatively slight; the error in estimating is also slight. Under the conditions of the experiment variants D and E had a relative sensitivity of 4,7 and 5,7. Our experience is that in average weather conditions in summer a figure 4 denotes a sensitivity which is proof against pastures with a normal occupancy. Greater sensitivity may lead to high yield losses.

7. Conclusion

The usefulness of the vegetation unit classification compiled by DE BOER was proved by two investigations. In the two sandy areas the vegetation unit was an index of yield, use-value, moisture supply, and to a lesser extent of soil fertility factors. Improvement measures can be carried out with the help of the information thus obtained.

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