EXAMINATION OF SOILS AND CROPS AFTER THE INUNDATIONS OF 1st FEBRUARY, 1953 [1])

I SALTY SOILS AND AGRICULTURAL CROPS

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Summary

A few months after the flood disaster of 1st February 1953, the greater part of the inundated area was dry again. Investigation of the soil of this area yielded the following data :

1 The salt content of the soil remained approximately constant during the summer, and fell considerably during the winter, in spite of scanty precipitation. This must be attributed to the high permeability of the top layer of soil, as a result of application of a gypsum dressing.

2 The crops which had been standing in the field on 1st February, and had been inundated, reacted especially to the salt content after the land had become dry again, whereas 20–50 days of submersion in water produced, in itself, only a moderately detrimental effect. Red clover, however, was very susceptible to standing under water.

3 Spring barley, yields of which were investigated in many small trial plots, reacted to the salt in the soil more or less according to expectations. The result corresponded well with results obtained earlier, in the years 1946–1948. The later the crop was sown, the greater was the harmful effect of the salt.

4 Other summer crops, such as oats, sugar beet, potatoes, flax and peas reacted to the salt in the soil approximately as they had done in the years 1946–1948. Sensitivity to salt increased in the order given in this article. The outcome, as compared with earlier results, was more favourable in the case of potatoes, and less favourable in the case of flax. This was dependent, in the first place, on the weather in 1953, which was dry in spring but wet in summer. Viewed over the whole growing period, the weather was about normal.

5 Heavy rain in the spring of 1953 started a deterioration in soil structure. On the basis of the relation between the salt index of the soil and adsorbed sodium, it was possible to determine how much gypsum was necessary for the individual types of soil in order to prevent serious structural deterioration. Despite the scanty rainfall the effect of gypsum on the soil structure was very great.

Introduction

The flood disaster of 1st February, 1953, in the Netherlands resulted in the inundation of an area about 160,000 hectares in size. During these floods, which took such a toll of human life and caused so much damage, water levels occurred which were higher than had ever been known before in the history of the regions concerned. The reason for this must be sought in the fact that a spring tide virtually coincided with the violent piling-up of masses of water in the tidal inlets of the Dutch coast in consequence of a prolonged storm.

More than 500 breaches were counted in the outer dams (i.e., the dams immediately in contact with the sea or its arms). Not all the breaches were equally serious, and consequently many could quickly be repaired. Accordingly, by 1st May, 1953, 120,000 hectares of cultivable land were dry once more.

Agricultural examination of soils flooded by salt water, carried out in 1945–1949, was continued in 1953. In this and in some following articles an account will be given of certain results achieved by the examination.

The salt content of the soil

With the object of providing the farmers with information a very large number of soil samples were examined for salt in March/April 1953. In the Netherlands, the salt content of soil is expressed by the "salt index", which

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represents the number of grams of NaCl per litre of moisture in the soil (VAN BEEKOM et al., 1953).

As was expected, the salt indices for the various regions differed considerably from each other. The chief reasons for this were:

1 dilution with river water of the sea water piled up between the islands;
2 duration of inundation.

The result of the examination for salt content is shown in Fig. 1.

Inland, the figures are low, owing to strong dilution of sea water by fresh river water, whereas on the sea coast very high figures occur.

Sea water has a salt index of 33; in the saltest soils the figure was over 20, but nowhere had the soil solution been entirely replaced by sea water.

Even within a small, self-contained area – a polder, for example – the salt index, or C value, varied considerably from place to place, owing to slight differences in elevation of the ground, treatment of the soil before the floods took place, vegetation at the time of the floods, etc. (cf. also VAN BEEKOM et al., 1953).

After the waters had receded, the trend of the salt indices in many places was investigated by means of monthly soil analyses. In Table 1 the data found are given for very salt, moderately salt, and slightly salt soils. The course taken by the moisture content (A) and the salt content (B), as well as that of the salt index (C), are all shown. In each group the results from various locations of examination have been averaged.

Table 1. Course of the moisture content (A), the salt content (B), and the salt index (C), in the top layers of inundated soil.

Layer 0–5 cm.

Date	Very salt			Moderately salt			Slightly salt		
	A	B	C	A	B	C	A	B	C
Middle of March, 1953 ..	25.7	0.80	31.1	18.1	0.43	23.7	19.1	0.21	11.0
Middle of April, 1953 ..	21.1	0.53	25.1	22.9	0.19	8.3	20.4	0.10	4.9
End of May, 1953	18.3	0.66	36.1	17.0	0.45	26.5	19.8	0.16	8.1
End of June, 1953	14.9	0.43	28.8	17.2	0.19	11.0	19.5	0.05	3.6
Middle of August, 1953 ..	14.1	0.49	34.7	17.8	0.27	15.2	12.7	0.06	4.7
End of September, 1953 .	20.4	0.24	11.8	21.5	0.08	3.7	22.1	0.03	1.3
Middle of November, 1953	17.3	0.21	12.1	17.7	0.10	5.6	18.5	0.03	1.6
Beginning of January, 1954	27.7	0.03	1.1	28.1	0.02	0.7	28.4	0.01	0.4
Middle of February, 1954	32.0	0.01	0.3	31.8	0.01	0.3	27.7	0.01	0.2

Layer 5–20 cm.

Date	Very salt			Moderately salt			Slightly salt		
	A	B	C	A	B	C	A	B	C
Middle of March, 1953 ..	25.1	0.49	19.5	22.8	0.30	13.1	24.5	0.18	7.3
Middle of April, 1953 ..	23.2	0.36	15.5	24.1	0.26	10.8	24.2	0.14	5.8
End of May, 1953	20.9	0.33	15.8	19.4	0.29	14.9	18.9	0.14	7.4
End of June, 1953	21.4	0.33	15.4	21.7	0.28	12.9	20.5	0.13	6.3
Middle of August, 1953 ..	20.6	0.33	16.0	21.8	0.24	11.0	18.6	0.08	4.3
End of September, 1953 .	22.0	0.26	11.8	22.3	0.16	7.2	20.5	0.07	3.4
Middle of November, 1953	20.7	0.23	11.1	21.5	0.15	7.1	20.0	0.06	3.0
Beginning of January, 1954	23.1	0.20	8.7	25.0	0.11	4.4	25.3	0.05	2.0
Middle of February, 1954	26.1	0.08	3.1	26.2	0.05	1.9	29.0	0.02	0.7

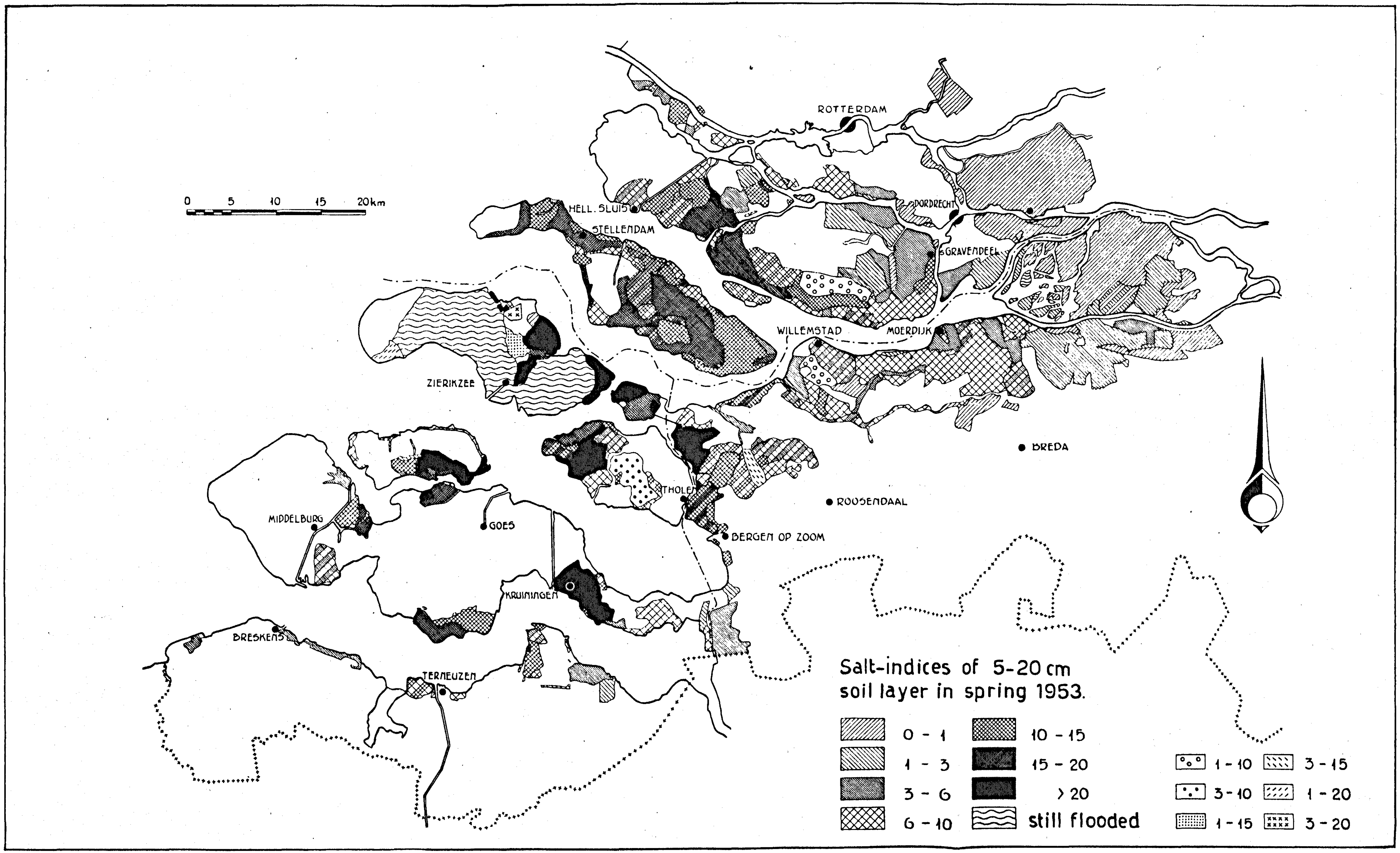


FIG. 1. MAP SHOWING SALT INDICES IN THE FLOODED REGIONS.

Desalting during 1953–1954 can thus be seen to have progressed very favourably, despite the fact that the amount of rain was considerably less than normal. Table 2 gives a summary of the rainfall.

Table 2. Rainfall in the Southwestern Netherlands (mm).

		1953/1954	Average over 40 years	
March	1953	8	44	March
April	,,	59	46	April
May	,,	27	49	May
June	,,	82	56	June
July	,,	66	68	July
August	,,	122	69	August
September	,,	44	67	September
October	,,	7	70	October
November	,,	13	73	November
December	,,	43	65	December
January	1954	47	59	January
February	,,	37	41	February
March	,,	46	44	March

Thus, the months of March and May 1953, were very dry, but the high rainfall from June until the beginning of September even had a desalting effect (cf. Table 1). In spite of the dry months of October, November and December, desalting during the winter of 1953/1954 was highly satisfactory. It can be said that every 40 mm of rain that winter reduced by half the salt index in the soil layer 5–20 cm.

This good result was due, in the first place, to timely application of gypsum. For in September/November 1953, a quantity of gypsum was strewn on all inundated soil, after tilling. Owing to this, the structure of the soil at the surface remained in good condition, and it was possible for all rain to penetrate the soil immediately, entraining salt from the top layers. The effect of gypsum on the settling of water can be seen, for instance, in Fig. 11.

The crops in 1953

The investigation of the growth of field crops was carried out on crops which were standing in the field during the floods (these crops had been sown in 1952, or before), and on crops sown after the land had become dry again in 1953.

a Inundated crops. In various fields a patch was selected, in which the salt index of the layers 0–5 and 5–20 cm was determined. The stand of the crop was evaluated several times by awarding it a figure in the scale 0–10. Investigation of these crops was mainly concerned with two factors, viz.:

1 salt index,
2 duration of inundation.

As an example of the way in which the data were processed, the results for winter wheat are given in rather more detail.

Investigation of winter wheat was carried out on 75 plots of ground. The soil in these plots consisted of light clay with a pH of 6.5–7.5, and in highly fertile condition. It was, however, found necessary nevertheless to take into account various factors such as nitrogen fertilization, ground-water level, the structure of the soil, etc., in order to ascertain the pure effect of salt index and inundation. For the influence of the salt index two curves were plotted, as shown in Fig. 2. The stand figures are those for June, 1953.

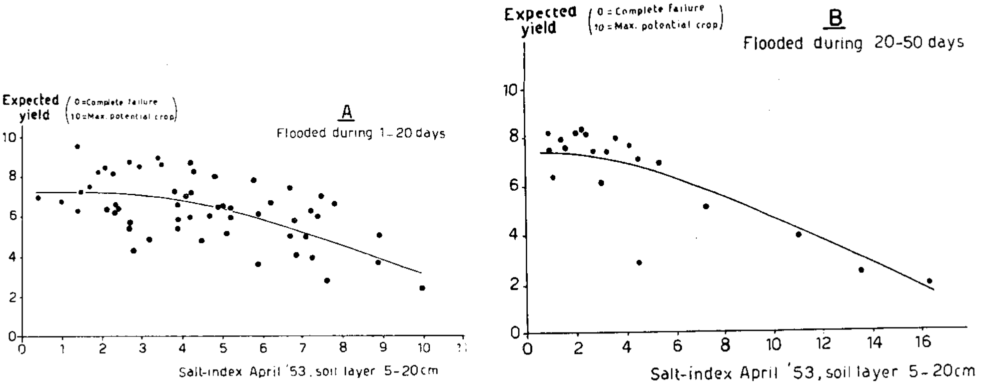


FIG. 2. THE EFFECT OF THE SALT INDEX (LAYER 5—20 CM) ON THE STAND OF INUNDATED WINTER WHEAT.

A : for duration of inundation 1—20 days.
B : for duration of inundation 21—50 days.

From comparison of these curves, it will be seen that, on an average, the effect of the salt index was rather more pronounced in the case of the crop which had been flooded for more than 20 days.

The effect of duration of inundation is shown in Fig. 3.

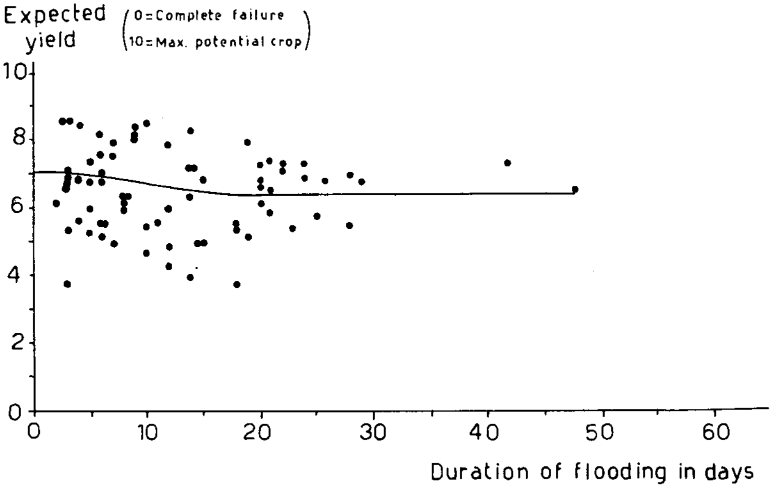


FIG. 3. EFFECT OF DURATION OF INUNDATION ON WINTER WHEAT.

In order to be able to construct this graph, it was nececssary to apply a correction for the influence of the salt index. This was done by correcting the stand figures in Fig. 2 as for a salt index of 4.5. From Fig. 3 it can now be seen that, if the salt influence is eliminated, the duration of inundation has left only a slight noticeable effect.

The statistics available were treated in the same way in the case of grass (for seed), grass (for grazing), winter rye, caraway, red clover; and if, in respect of all these crops, the stand figures for approximately normal plants are considered as representing 100%, it becomes possible to carry out a comparative investigation of the effect of the salt index on the various crops. Fig. 4 gives a picture of this.

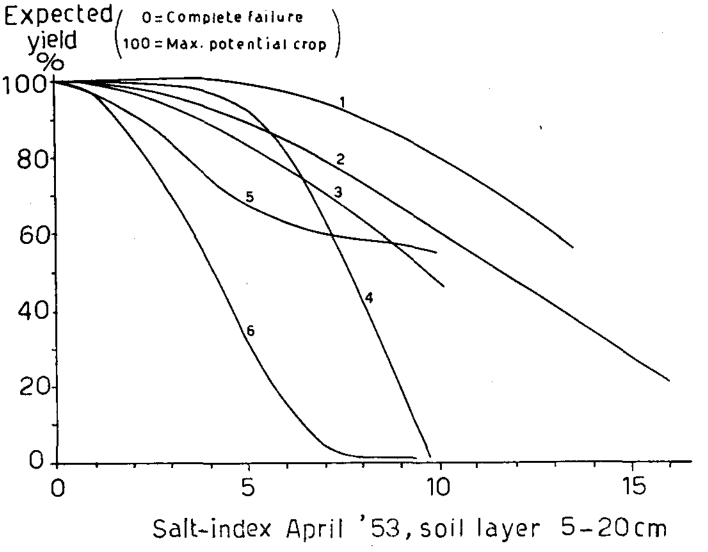


FIG. 4. THE EFFECT OF THE SALT INDEX ON THE RELATIVE STAND FIGURES (JUNE, 1953) FOR INUNDATED CROPS.

1 grass (for seed).	4 winter rye.
2 winter wheat.	5 caraway.
3 grass (for grazing).	6 red clover.

The relative susceptibility to salt of the crops investigated can be read off directly from this figure. The susceptibility increases in the order 1–6.

A similar diagram can also be compiled to show the effect of duration of inundation. Accordingly, a correction has always been applied for the influence of the salt, in this case. Fig. 5 shows the relation between the stand of the crop and the duration of inundation.

From this investigation, the following conclusions can be drawn:

1 At a time of year in which the plants are not growing much (February), the majority of plants can endure a flood lasting from 20 to 30 days without suffering much damage, provided the flood water contains only little salt. Red clover, however, is very sensitive to such an inundation.
2 In the case of an inundation period lasting from 20 to 50 days, the influence of the soil's salt index is much more important than the duration of inundation.
3 The sensitivity to salt of the perennial crops, grass (for seed) winter wheat, grass (for grazing), winter rye, caraway, red clover, increases in the order given above.

b Spring barley. In 1953, spring barley was sown on very many soils from which the water had receded. It was already known that barley, under Netherlands conditions, is highly resistant to salt. (VAN DEN BERG, 1950 and 1951; VAN BEEKOM et al., 1953).

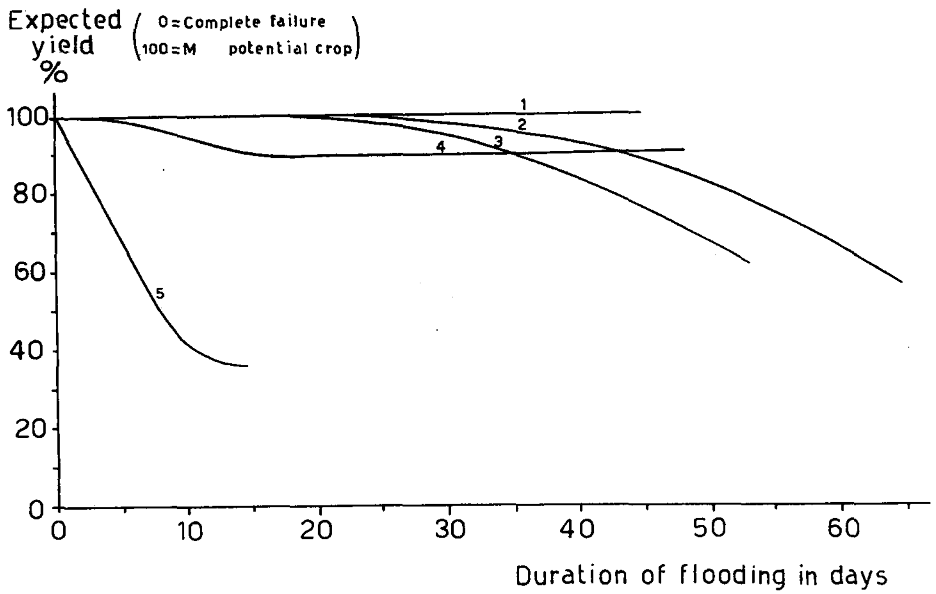


FIG. 5. THE EFFECT OF DURATION OF INUNDATION ON THE STAND OF INUNDATED CROPS, IN JUNE, 1953.

1 winter barley and winter rye.
2 caraway.
3 grass (for seed).
4 winter wheat.
5 red clover.

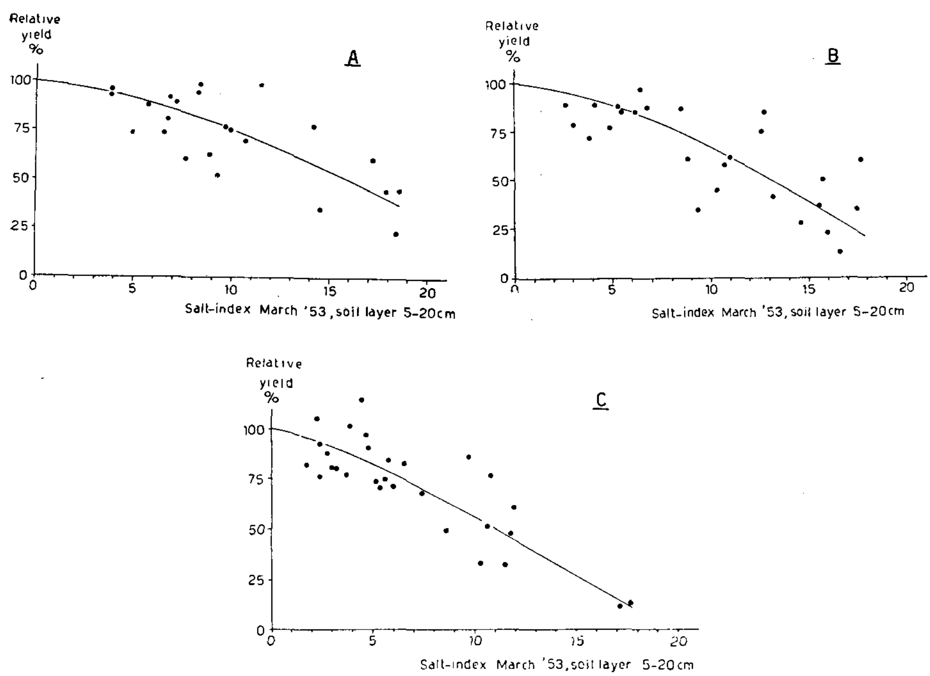


FIG. 6. INFLUENCE OF THE SALT INDEX ON THE GRAIN YIELD OF KENIA SPRING BARLEY, 1953.

A Sowing period, 8th March–26th March.
B ,, ,, 27th March–15th April.
C ,, ,, 16th April –10th May.

This investigation, like that carried out on the inundated crops, was performed by selecting a patch in each of various fields, from which patch all kinds of data were collected, including the salt index of the top layers of the soil.

The yield from 25 square metres was precisely determined. It was found desirable to take into consideration not only the influence of the salt index of the soil, but also the date on which the crop was sown.

The results of the investigation are shown in Fig. 6, in which three sowing periods are distinguished.

Various influences caused the great variation in yield between soils with a certain salt index. For instance, the differences in fertility level and the water condition of the soil played a part; but the effect of these factors was not investigated further. In the case of higher salt indices, the average yield shows a regular decline and this decline is the more pronounced the later the time of sowing.

If the average result for 1953 is compared with that for earlier years, it will be seen that the influence of the salt index lies exactly between that shown in the highly unfavourable results for 1947, and that shown in the highly favourable results for 1946 and 1948 (Fig. 7).

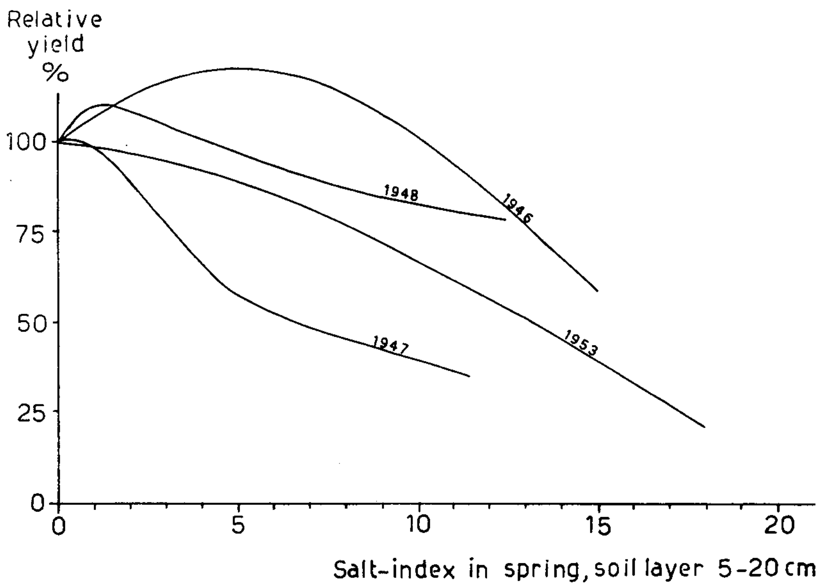


FIG. 7. COMPARISON OF THE AVERAGE YIELD LINES FOR KENIA SPRING BARLEY ON SALT SOILS IN 1946, 1947, AND 1948, WITH THAT FOR 1953.

In the Netherlands, the growing season for spring barley is from March to July. As far as weather conditions were concerned, that period of the year 1953 can be regarded as having been more or less normal, because the scanty rainfall in the months of March and May was made up for by the abundant rain in the months of April and June. The temperature during that period varied little from the normal.

Variety trials of spring barley proved that the Danish variety Balder was highly salt-resistant – more so than the varieties Kenia and Saxonia.

c Other crops sown in 1953. Just as in 1946, 1947 and 1948 (Van den Berg, 1951), trials with various crops in fields of differing salt indices were also undertaken in 1953. A number of crops were sown or planted in duplicate in each trial field. The yield from 25 to 30 square metres was determined in each case.

In this way, a graph of points could be compiled for each crop, on the lines of Fig. 2 and Fig. 6. It was possible to compare the crops with each other by constantly determining the yields in relation to those from normal soils. The result for 1953 is shown in Fig. 8.

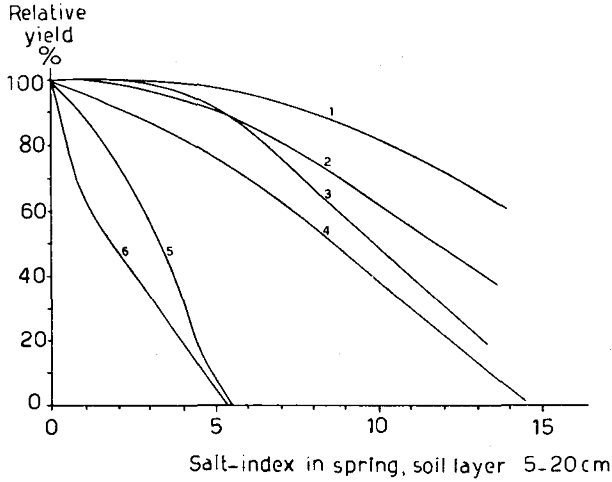


Fig. 8. Average result from various crops in trial fields of differing salt indexes.

1	spring barley.	4	potatoes.
2	oats.	5	flax.
3	sugar beet.	6	peas.

The relative degree of susceptibililty to salt exhibited by the crops examined is shown by the numbering in Fig. 8, according to which spring barley is prominent as highly resistant.

Comparison of these data with those relating to the years 1946–1948 (Van Beekom et al., 1953) shows that the sequence of resistance is practically the same. The only point of difference was that flax development in 1953 was very unfavourable as a result of the dry spring season, whereas potatoes made a very favourable showing.

The result already seen in the case of spring barley (Fig. 7) also applies to most of the other crops – viz., the outcome for 1953 lies between those for 1947 and 1948. It may be said of the results for 1953, in all respects, that they are more or less to be expected in the Netherlands in a year in which the weather can be termed normal.

The structure of the soil

Even comparatively small quantities of adsorbed sodium exert a strong effect on the structure of the soil (Van Beekom et al., 1953; Kelley, 1951). It was very important quickly to obtain a comprehensive general view of the adsorbed sodium in all kinds of soil, because gypsum was to be distributed for the purpose of preventing or restricting structural deterioration, and the quantity of gypsum required is connected with the quantity of adsorbed sodium.

The method of determining salt content in the Netherlands is conducive to the fact that a certain connection is to be expected between the salt index and the quantity of adsorbed sodium. For the salt index is calculated from a determination of the chlorine content of the soil, and chlorine is strongly correlated with sodium. As regards this connection, however, it will be necessary to take as point of departure that soil material which adsorbs cations to a strong degree, and not soil as such. For this reason, the number of milli-equivalents of adsorbed sodium per 100 grams of adsorbent material was determined in many samples. The sum of the total clay content and three times the humus content was taken as adsorbent material for this purpose (VAN BEEKOM et al., 1953).

The method is based on soil, the clay and humus content of which have been determined separately. Part of the soil is eluted with an 80 % solution of alcohol until all soluble salts have been washed out. This is checked by reference to the Cl. The eluted soil is then percolated with 1 N. NH_4NO_3, and sodium is determined in the percolate.

The fairly close connection between the salt index and adsorbed sodium found in this way can be read from Fig. 9.

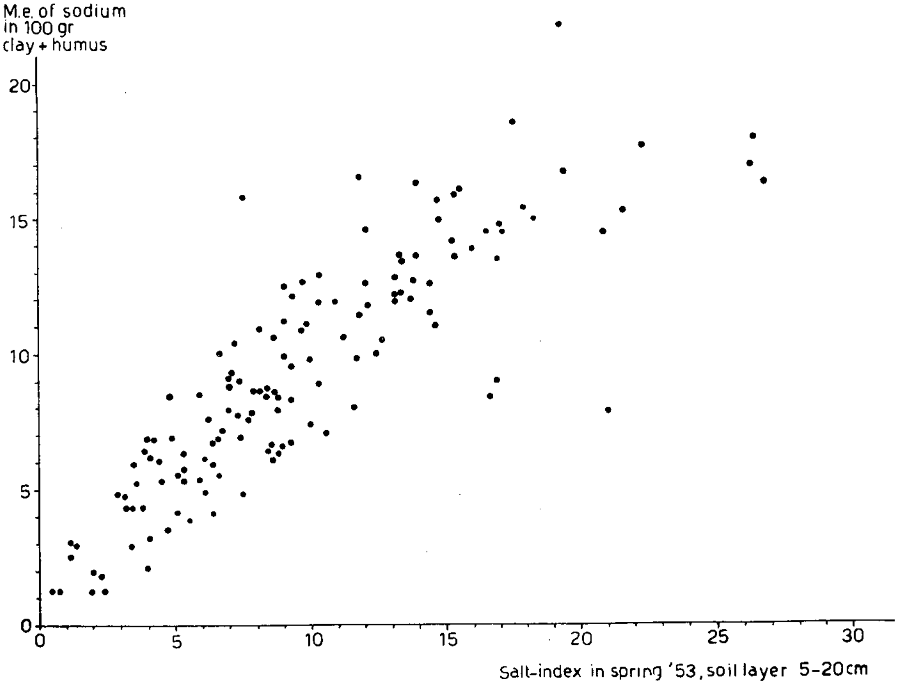


FIG. 9. THE CONNECTION BETWEEN THE SALT INDEX OF THE SOIL AND ADSORBED SODIUM IN 100 GRAMS OF CLAY AND HUMUS. SPRING, 1953.

Owing to the fact that very many determinations of the salt index were available, it was a very simple matter to deduce the quantities of adsorbed sodium per 100 grams of clay + humus. These figures, however, still did not give an idea of the amounts of adsorbed sodium per unit of soil, and the latter quantity must be known in order to determine the amount of $CaSO_4.2$ aq. which is required to preserve the soil from serious structural deterioration. It is therefore necessary to know the amount of adsorbent material present in the soil. In the Netherlands, this can be fairly accurately ascertained by estimating the clay content, because the relation between the contents of clay and humus in old arable land is known. And it is just in this old arable land, containing little humus, that accurate determination of the exact amount of gypsum is important, because in such soils structural deterioration is a serious problem and is much more pronounced than in soils rich in humus.

It was possible to establish the quantity of gypsum needed for each type of soil from the estimated clay contents (the adsorbing material in this case) and the amount of adsorbed sodium (ascertained via the relation with the salt index), because the connection between adsorbed sodium and gypsum requirements had been determined by means of trial field experiments in the years 1946—1952 (WESTERHOF, 1950; VAN BEEKOM et al., 1953).

Of course, the requisite amount of gypsum for a soil can also be computed theoretically from its content of exchangeable sodium, but, in doing so, fairly considerable losses owing to the leaching of gypsum must be taken into account, on the one hand, and a natural recovery of the soil, especially when free $CaCO_3$ is present, must be taken into account on the other hand.

As a rule, deterioration in the soil structure in the first six months after a flood is slight, because the high salt content keeps the soil in a flocculated condition. But in 1953 distinct signs of deterioration in structure were visible as early as April. This was due to the fact that about 40 mm of rain fell on

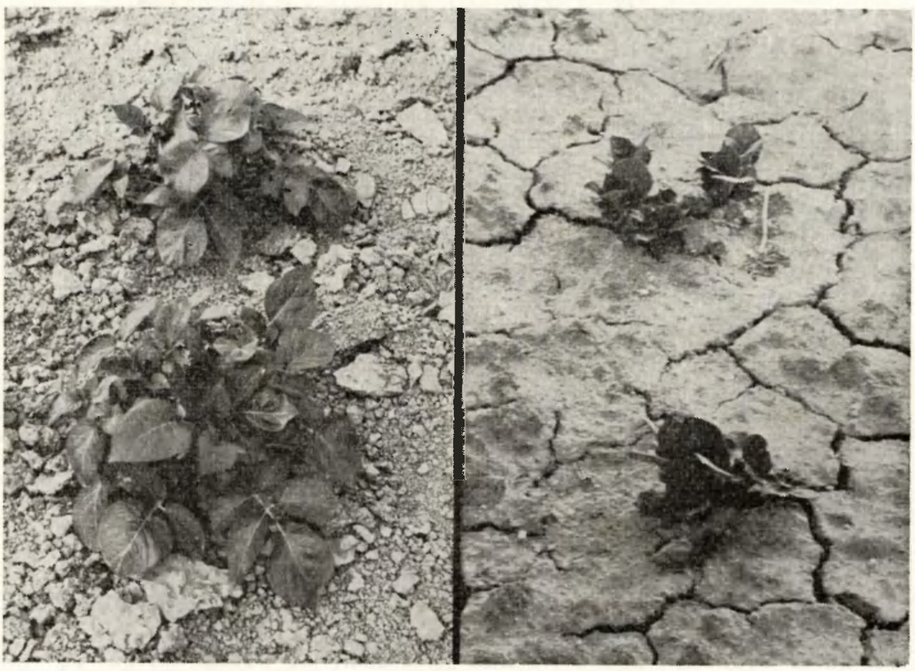
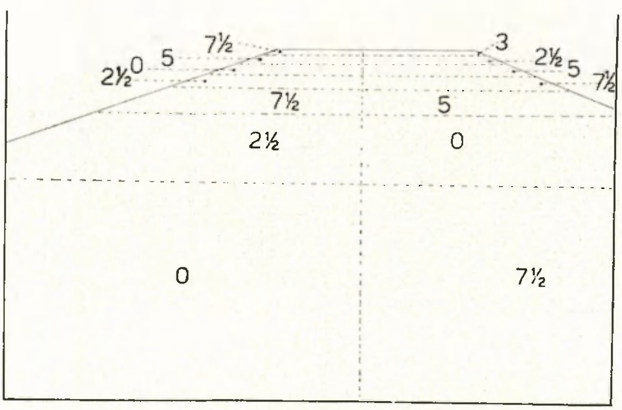


FIG. 10. POTATOES ON SALT SOILS IN JUNE, 1953.
Left: almost normal structure, in only slightly salt soil (C = 3.7).
Right: poor structure in salt, heavy soil (C = 7.6).

3rd and 4th April, 1953, so that the top few centimetres of soil lost a great deal of salt, and started becoming dispersed. The photograph in Fig. 10 shows the condition of a salt soil in June, 1953. For purposes of comparison a view is also given of a portion of less salt ground, where little or no decline in structure occurred.

In sundry cases the thin crust formed on many salt soils prevented the crop from coming up, until cracks made it possible for the young plants to emerge. In the spring, the ill effects of the formation of such a crust are chiefly confined to sprouting. Experience has shown that once plants have sprouted they are not particularly hindered by structural deterioration on the surface.

Fig. 11. Gypsum trial field on salt soil, February, 1954. (The quantities of gypsum administered are shown in the sketch, in metric tons per hectare).



Structural deterioration is most clearly visible after a wet period, when the effect of gypsum is also strongly in evidence. Fig. 11 gives a picture of a gypsum trial field in February 1954.

In practice, an amount of 6 metric tons of gypsum per hectare will be supplied for this soil; comparison with the effect of 5 and 7½ metric tons of gypsum on the trial field clearly shows that the top of the soil is sufficiently permeable.

There is therefore good reason to hope that, owing to distribution of all the gypsum in 1954/1955, most of the difficulties with the inundated soils will be overcome in the course of 1955.

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