# THE OCCURRENCE OF TWO ALKALI SOILS IN ZULULAND

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## Introduction

Alkali and Saline soils occur mainly in regions of semi-arid or arid climate, large-scale examples being found in the western U.S.A. ([3], [4] and [5]), the Punjab of India[2], Egypt[6], and in south-western Puerto Rico[1]. In many cases the process of soil salinisation and alkalisation is accelerated by injudicious irrigation practices and poor drainage. Most forms of alkalinity or salinity are derived primarily from the underlying rocks or soil profile, but in some cases the development of a saline or alkali soil may be due to irrigation with water that contains large amounts of soluble salts. The saline or alkali constituents of a rock are liberated on decomposition and will accumulate in the soil unless removed either by solution or some other agency.

In humid regions with an adequacy of rainfall the alkali or saline salts being readily soluble, are leached out of the soil and removed by rivers to the ocean. Conversely in semi-arid or arid regions, having a high evaporation rate and low rainfall, the salts will tend to accumulate in the soil. Thus when semi-arid or arid soils are irrigated with copious amounts of water (as it often the case in the early stages of development of an irrigation scheme), there will be a tendency for the water-table to rise unless adequate provision for drainage is made. As the water-table in arid areas is ordinarily deep, with its rise induced by over-irrigation, most of the salts distributed throughout the lower portions of the profile will be concentrated by evaporation at the surface.

Although many alkali and salinity problems are man-made, it should be recognised that the occurrence of alkali and saline areas is related directly to climatic conditions and to the chemical composition of the soil forming materials derived from the parent rocks.

## Terminology

In view of the differences in terminology in numerous publications dealing with alkali and saline soils, the U.S. Salinity Laboratory has published a terminology and description of alkali and saline soils[5]. The terms thus defined are given below:

*Alkali soil*—A soil that contains sufficient exchangeable sodium to interfere with the growth of most crop plants, either with or without appreciable quantities of soluble salts.

*Nonsaline—Alkali soil*—A soil that contains sufficient exchangeable sodium to interfere with the growth of most crop plants and does not contain appreciable quantities of soluble salts.

*Saline—Alkali soil*—A soil containing sufficient exchangeable sodium to interfere with the growth of most crop plants and containing appreciable quantities of soluble salts.

*Saline soil*—A non-alkali soil containing soluble salts in such quantities that they interfere with the growth of most crop plants.

Thus "alkali" refers to the presence of excessive exchangeable sodium and "saline" to excess salts in the soil.

## The Occurrence of Two Alkali Soils in Zululand

The occurrence of alkali and saline soils is uncommon in the sugar-belt of Natal and Zululand, but during the course of the soil survey now being undertaken in Zululand, two areas of severe alkalisation of the soil were found. They occur a few miles apart, in the Heatonville district, west of Empangeni, in an area of low rainfall (24-30″ annually). On account of this low rainfall irrigation of cane-fields is practised, as it is extensively done higher up the same valley in the Nkwaleni area.

The soil on which the occurrences are found is in the one case an alluvial derived mainly from Beaufort sediments while the other occurs directly on Beaufort sediments. In the former case although the natural vegetation has not died out only very hardy salt brush and grass are able to survive on an area some 4-5 acres in extent. Scattered patches of bare soil with a white salt encrustation are found in the centre of the affected area. The area so affected occurs in the bottom of a shallow valley with hills of Beaufort sediment on either side.

In the latter case the affected area is situated on a moderate hill-slope overlooking the Umhlatuzi river. In this case the degree of alkalisation of a former cane-field is so severe that all vegetation has died out, being replaced over an area some 3-4 acres in extent by a hard crust of white salts. (Plate 1.)

In the former area test-pit 1624 was sited while on the latter T.P.'s 1630 A and 1630 B, were dug. T.P. 1630 A was located higher up the slope than T.P. 1630 B which was also situated toward the side of the alkali area. T.P. 1626 was dug in order that a comparison between alkali profiles on Beaufort sediments and a normal Beaufort soil profile (in which T.P. 1626 is located), might be established.

## Characteristics of the Soils Studied

The results of particle size analyses are given in Table I.

# TABLE I

**Particle Size Distribution Data for the Soils Studied**

| Sample | %Coarse Sand and Gravel 10—0.2 mm. | % Fine Sand 0.2—0.02 mm. | % Silt 0.02—0.002 mm. | % Clay less than 0.002 mm. | Textural class |
|---|---|---|---|---|---|
| | | T.P. 1624 | | | |
| 0″— 2″ | 26.39 | 63.25 | 2.19 | 8.17 | Sand |
| 2″— 4″ | 11.19 | 71.20 | 6.37 | 11.24 | Fine sand |
| 4″— 6″ | 1.79 | 73.17 | 10.43 | 14.61 | Silty fine sand |
| 6″—14″ | 2.53 | 40.01 | 27.91 | 29.55 | Fine sandy loam |
| 14″—44″ | 1.73 | 34.71 | 25.68 | 37.88 | Clayey fine sand |
| 44″—52″ | 1.65 | 40.26 | 20.22 | 37.87 | Clayey fine sand |
| | | T.P. 1630 A | | | |
| 0″— 2″ | 55.60 | 22.20 | 5.14 | 17.06 | Loamy coarse sand |
| 2″— 4″ | 56.28 | 21.86 | 4.42 | 17.44 | Loamy coarse sand |
| 4″—10″ | 51.70 | 24.15 | 3.47 | 20.68 | Loamy coarse sand |
| 10″—16″ | 42.32 | 28.84 | 4.14 | 24.70 | Loamy coarse sand |
| 16″—32″ | 34.37 | 32.72 | 6.10 | 26.71 | Sandy Loam |
| | | T.P. 1630 B | | | |
| 0″— 2″ | 33.57 | 42.14 | 7.27 | 17.02 | Loamy sand |
| 2″— 6″ | 37.89 | 34.71 | 9.12 | 18.28 | Loamy sand |
| 6″—18″ | 37.62 | 34.36 | 8.56 | 19.46 | Loamy sand |
| 18″—36″ | 31.55 | 30.91 | 11.27 | 26.27 | Sandy loam |
| | | T.P. 1626 | | | |
| 0″— 8″ | 29.25 | 54.19 | 2.53 | 14.03 | Loamy fine sand |
| 8″—22″ | 23.92 | 47.38 | 4.13 | 24.57 | Fine sandy loam |
| 22″—32″ | 15.73 | 46.92 | 3.52 | 33.83 | Fine sandy loam |
| 32″—36″ | 24.87 | 36.38 | 2.86 | 35.89 | Fine sandy loam |

These data show that in the case of T.P. 1624, the soil to a depth of 6 inches is composed mainly of sand, while below this to a depth of 52 inches the soil becomes much finer in texture with higher percentages of silt and clay. At a depth of 52 inches the water-table was encountered. This sandy layer overlying the lower more clayey soil represents recent stream flood deposits, attributable to the small stream which flows through the centre of the area.

In T.P.'s 1630 A and 1630 B the soil is sandy textured throughout the profile with very little silt and clay. As has been mentioned previously these two T.P.'s are situated in the same area some 30 yards apart. In these two pits the water-table was encountered at the very shallow depth of 24 inches. It was impossible to dig these two T.P.'s deeper than about this depth as they rapidly filled with a water highly charged in soluble salts. (Table II No. 3.) T.P. 1626 is sandy throughout its depth, though the sand is finer than in the two preceding T.P.'s. At a depth of 44 inches weathering rock was encountered.

TABLE II

**CHEMICAL COMPOSITION OF WATERS IN DRAINS AT ALKALI SOIL OCCURRENCES**

| | Electrical conductivity at 25°C mmhos/cm. | Dissolved solids ppm. | Sum of cations | Cations meq/L | | | | Anions meq/L | | | | Soluble Na per cent | Sodium absorbtion ratios |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Na | K | Ca | Mg | Cl | $SO_4$ | $HCO_3$ | $CO_3$ | | |
| 1 | 5.9 | 4162 | 72.12 | 66.96 | 0.09 | 0.79 | 4.28 | 45.20 | 4.94 | 19.60 | 3.60 | 92.85 | 42.03 |
| 2 | 625.0 | 19220 | 296.33 | 246.52 | 0.24 | 7.28 | 40.29 | 247.00 | 8.95 | 15.50 | 7.00 | 83.76 | 50.56 |
| 3 | 340.0 | 14810 | 227.18 | 186.96 | 0.18 | 9.28 | 30.76 | 221.00 | 7.75 | 23.00 | — | 82.30 | 41.80 |

pH 1,—9.2, 2,—7.9, 3,—8.0
1 — Drain water at T.P. 1624
2 — Drain water at T.P. 1630 A
3 — Water in T.P. 1630 B

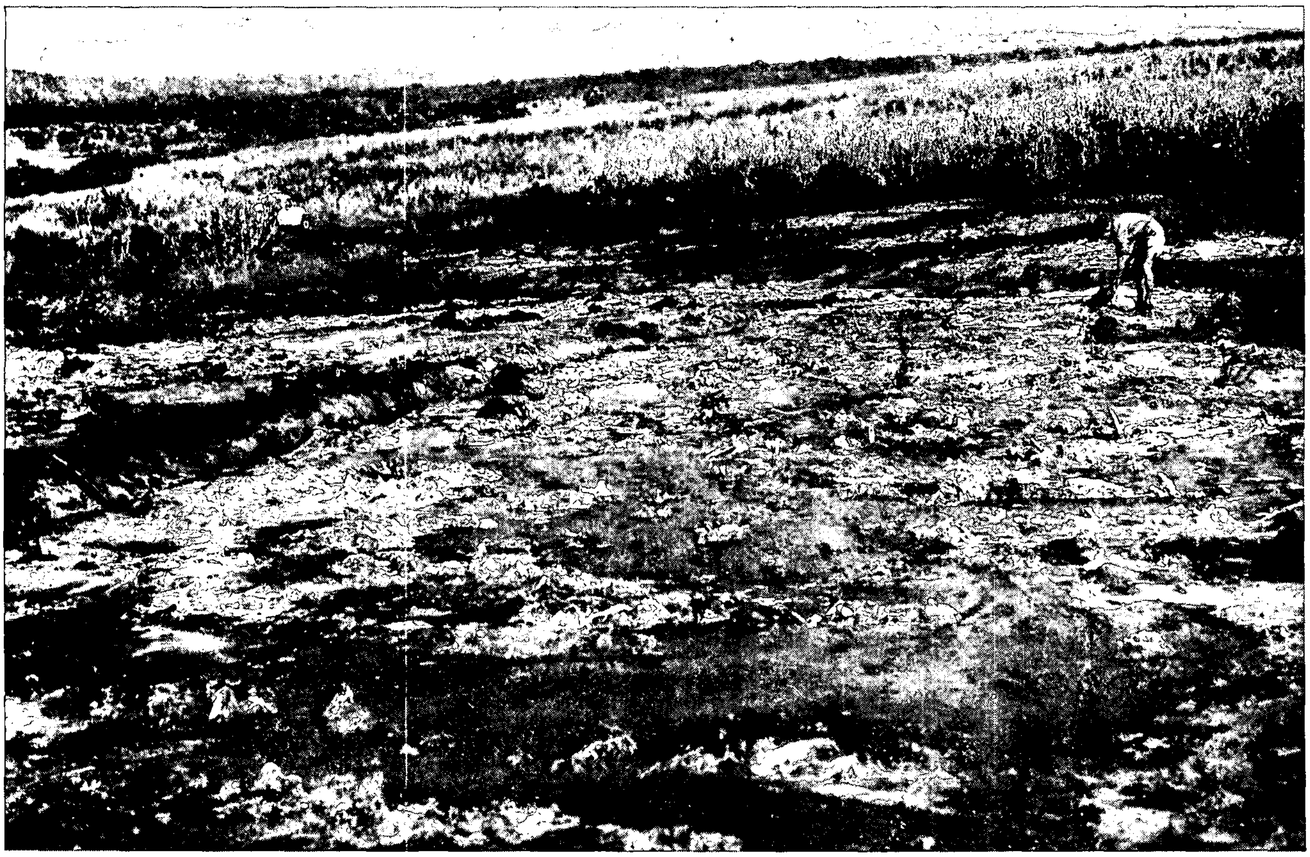
The results of chemical determinations made to characterise the soils at these locations are given in Table III.

TABLE III

**CHEMICAL CHARACTERISTICS OF SOILS STUDIED**

T.P. 1624

| Sampling Depth | pH of 1:2.5 soil : soln. suspension | % Organic Matter | Saturation extract determinations Milliequivalents per litre | | | | | | | | Electrical conductivity of sat. ext. at 25°C mmhos/cm. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Na | K | Ca | Mg | Cl | $SO_3$ | $HCO_3$ | $CO_3$ | |
| 0″— 2″ ... ... | 9.4 | 0.50 | 560.87 | 1.05 | 8.73 | 76.48 | 645.00 | 55.25 | 7.50 | 2.00 | 71.0 |
| 2″— 4″ ... ... | 9.0 | 0.56 | 117.39 | 0.19 | 1.75 | 12.33 | 127.00 | 11.00 | 4.50 | — | 14.0 |
| 4″— 6″ ... ... | 7.9 | 1.14 | 123.91 | 0.23 | 1.75 | 14.80 | 146.00 | 10.56 | 2.25 | — | 14.0 |
| 6″—14″ ... ... | 7.0 | 1.90 | 121.74 | 0.31 | 2.49 | 18.91 | 118.00 | 9.94 | 1.50 | — | 15.0 |
| 14″—44″ ... ... | 7.1 | 1.90 | 97.83 | 0.15 | 5.74 | 21.38 | 113.00 | 2.06 | 1.50 | — | 12.0 |
| 44″—52″ ... ... | 7.9 | 1.05 | 65.22 | 0.10 | 4.50 | 17.27 | 74.00 | 1.71 | 2.00 | — | 9.0 |
| | | | | | T.P. 1630 A | | | | | | |
| 0″— 2″ ... ... | 7.3 | 1.30 | 891.30 | 1.74 | 65.37 | 300.99 | 1135.00 | 32.82 | 5.00 | — | 120.0 |
| 2″— 4″ ... ... | 8.0 | 1.10 | 123.91 | 0.23 | 3.74 | 22.04 | 144.00 | 4.03 | 3.00 | — | 15.5 |
| 4″—10″ ... ... | 7.9 | 1.15 | 84.78 | 0.13 | 2.74 | 15.63 | 96.00 | 3.26 | 2.50 | — | 10.5 |
| 10″—16″ ... ... | 8.1 | 0.90 | 80.43 | 0.12 | 2.24 | 14.80 | 92.00 | 4.97 | 4.00 | — | 10.0 |
| 16″—32″ ... ... | 8.5 | 0.10 | 78.26 | 0.10 | 1.49 | 13.16 | 90.00 | 5.57 | 2.50 | — | 10.0 |
| | | | | | T.P. 1630 B | | | | | | |
| 0″— 2″ ... ... | 8.8 | 1.60 | 195.65 | 0.54 | 5.99 | 36.18 | 216.00 | 8.57 | 5.50 | — | 24.0 |
| 2″— 6″ ... ... | 7.9 | 1.90 | 119.56 | 0.50 | 3.49 | 20.56 | 132.00 | 7.80 | 3.00 | — | 15.0 |
| 6″—18″ ... ... | 7.7 | 1.40 | 100.00 | 0.31 | 7.23 | 23.85 | 125.00 | 1.89 | 3.00 | — | 13.5 |
| 18″—36″ ... ... | 8.5 | 0.20 | 108.69 | 0.18 | 3.24 | 21.38 | 124.00 | 6.51 | 2.50 | — | 13.0 |
| | | | | | T.P. 1626 | | | | | | |
| 0″— 8″ ... ... | 5.8 | 0.59 | 4.35 | 0.08 | 0.25 | 4.11 | 6.00 | 1.20 | 1.00 | — | 0.1 |
| 8″—22″ ... ... | 7.3 | 0.44 | 19.56 | 0.08 | 0.50 | 7.40 | 18.00 | 4.93 | 1.50 | — | 0.2 |
| 22″—32″ ... ... | 8.1 | 0.04 | 34.78 | 0.06 | 0.50 | 8.22 | 32.00 | 3.33 | 2.00 | — | 0.4 |
| 32″—44″ ... ... | 8.5 | Nil | 43.48 | 0.13 | 0.90 | 9.04 | 42.00 | 4.37 | 2.00 | — | 0.5 |



The view looking downslope from T.P. 1630 A, of the area affected by severe soil alkalisation. The main irrigation canal is upslope from the site of the photograph. Note the cultivation ridges indicating that the area was formerly a cane-field, and the relatively steep slope of the field affected. Ngoye mountains in the distance.

These data show that in T.P. 1624 the surface soil is highly charged with sodium chloride, other salts being relatively low by comparison, but only 2 inches below the surface the amount has fallen to about one fifth its former amount. This decrease in salt content is continued with depth, though the amount of decrease is not nearly so spectacular as that between the surface and second horizons. The increase in salt content in the third horizon can probably be explained by the migration of salts from the second to the surface horizon thus lowering its amount relative to the third horizon. The decrease in the salt content of the soil with depth in profile is shown diagrammatically in Fig. I.

The conductivity of the saturation extract of the soil, being directly related to the amount of soluble salts held in solution, is plotted diagrammatically against profile depth. As can be seen, the conductivity falls off sharply after the surface horizon.

The pH of the soil also decreases with depth from a highly alkaline surface pH of 9.4. The increase in the lowest horizon is probably due to the presence of the water-table. The organic matter is lowest in the sandy surface horizons but is in somewhat greater amounts in the clayey lower horizons.

T.P. 1630 A has even more sodium chloride in the surface layer than the previous case, but the amount gain decreases with depth. The abrupt decrease in salt content below the surface horizon is even more pronounced than in T.P. 1624 (Fig. 1), but conversely the pH increases with depth. As would be expected the amount of organic matter decreases with depth. The differing trends in pH between this and the previously discussed occurrence is possibly due to the presence of carbonates in T.P. 1624 while in T.P. 1630 A they appear to be absent.

In T.P. 1630 B the amount of salts present is much less than in either of the two previous instances. This may be attributable to its location, towards the border of the area, or possibly as it is further down the slope, some salts may have been removed by leaching, as the alkalisation of the soil took place first in the lower portions of the area. The drop in salt concentration with depth although not nearly so pronounced is still apparent (Fig. 1), while organic matter and pH also decrease with depth. The rise

**VARIATION OF SALT CONTENT WITH DEPTH IN PROFILE**

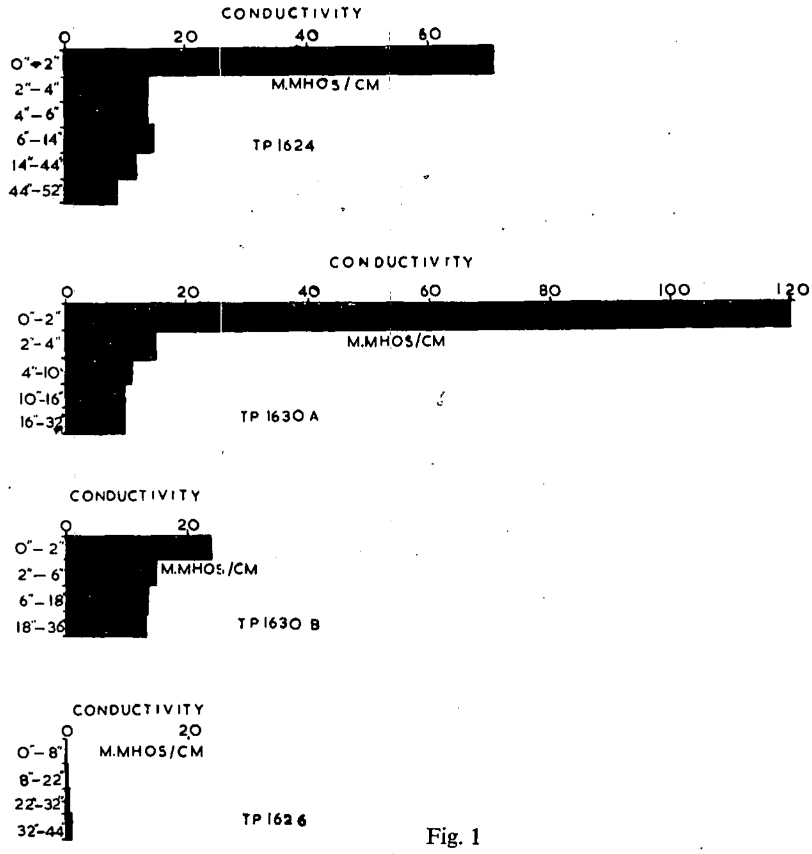



Fig. 1

in pH at the lowest horizon is probably again attributable to the presence of the water-table.

T.P. 1626 on a normal un-irrigated Beaufort soil, has but a fraction of the salts present in the former occurrences (Fig. 1). Although very small, there is a tendency for an increase of salt content with depth, which is the reverse of that found previously. Organic matter decreases with depth as is normal, while pH increases in the manner characteristic of normal Beaufort soils.

Thus the alkali soils, with which from their chemical characteristics and the foregoing definition they are to be classed, have a reverse tendency to the salt content of the profile horizons of normal soils. The salts are concentrated at the surface with lesser amounts at lower levels, while in normal soils the reverse is true.

### The Cause of the Alkali Accumulation

As has previously been stated, T.P. 1624 is located on a valley floor on an alluvial soil. The hills on either side of the valley are given over to cane cultivation, the fields at times being furrow-irrigated. As these hills are of coarse textured Beaufort soil, much seepage water finds its way down to the valley floor. As there is already a fairly high water-table under the valley, this seepage water raises it still further bringing to the surface there, both the salts leached from the surrounding hills and any which may occur naturally in the alluvial profile.

It must be stated here, that soils from Beaufort sediments appear to be more susceptible to alkali accumulation than do most other soils that occur in the sugar-belt. Alkali and saline areas however are known on middle Ecca soils, which closely resemble those of the Beaufort, as well as on various alluvial soils. This characteristic of the Beaufort soils is borne out by the fact that almost in Empangeni itself, where the rainfall is some 40 inches annually, an alkali area has developed on the Beaufort soil, where it has been saturated by seepage water.

In the case of T.P.'s 1630 A and 1630 B the alkali concentration is directly attributable to an unlined main irrigation canal some little distance further up the same hillside.

Water flowing in this canal has by seepage through the coarse sandy soil completely saturated the whole area below it, hence the very shallow water-table encountered in the two T.P.'s further down the slope. This rise of the water-table from some 30 to 40 feet deep, at which depth it would normally occur in this situation, to just below the surface, has concentrated all the salts in the surface zone.

An analysis of the river water used in both the preceding and former locations for irrigation purposes is given in Table IV.

From the analysis of this water, it is deduced that though it is a water of medium salinity it has a low

TABLE IV

**CHEMICAL COMPOSITION OF UMHLATUZI RIVER WATER**

| Electrical conductivity ECx $10^6$ at 25°C | Dissolved solids ppm | Sum of cations meq/L | Cations Meq/L | | | | Anions Meq/L | | | | Soluble Na % | Sodium absorbtion ratio * |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Na | K | Ca | Mg | Cl | $SO_4$ | $HCO_3$ | $CO_3$ | | |
| 390 | 266 | 3.72 | 2.22 | 0.33 | 0.41 | 0.76 | 1.60 | 0.15 | 3.60 | — | 59.68 | 2.88 |

*Sodium absorbtion ratio (S.A.R.) $= \frac{Na^{+}}{\sqrt{Ca^{++} + Mg^{++}/2}}$
pH. 7.2.

sodium hazard value. This analysis should be compared with that of the waters leaving the affected alkali areas. (Table II Nos 1 and 2.) That from the area of T.P. 1630 A is fully two-thirds as salty as sea-water. Thus the cause of the alkali accumulation cannot be attributed to the quality of the irrigation water used.

It is evident then, that in both localities of alkali occurrence, the cause is due to an artificial raising of the water-table, induced by an excess of water in the soil profile. This has concentrated at the surface the already somewhat high amounts of salts that exist in the rocks below. Under normal conditions the process of downward leaching or removal of salts would have continued but the raising of the water-table has resulted in the conditions being reversed.

## Possible Methods of Reclamation

In both alkali areas the main method of reclamation would be to prevent the further access of excessive amounts of water to the affected areas. In the case of the area around T.P. 1624 deep drains should be dug around the borders of the valley to prevent any seepage from the irrigated canefields above, while the valley-floor itself should be intensively drained on a herring-bone pattern.

The present surface salt encrustation could be scraped off or the salts allowed to be leached away by rainwater or surface applications of irrigation water of short duration followed by a period of dryness to allow the salts to again accumulate at the surface. The application of gypsum might assist matters thereafter. Filter-press cake at the rate of 20 to 30 tons an acre could be applied and this would do much to assist in the conversion of the soil back to a good crop producer again. In addition if the land were planted to cane, as presumably it would, the inter-rows should be ridged very high while the cane rows themselves should be in deep troughs. This high ridging will cause any remaining salts to be concentrated at the peaks of the ridges while the cane root growing area would be in a zone of very low salt concentration. The high ridges should be maintained throughout the cycle of crop growth and not flattened by weeding processes. Any salt accumulation in the ridges will in itself tend to suppress weed growth. Overhead irrigation should also be practised as furrow irrigation would not be possible in an extensively drained area.

The area around T.P.'s 1630 A and 1630 B could be reclaimed in much the same manner as just described, but the most important prerequisite would be the lining of the main irrigation canal with cement or some other impervious material. Thereafter the salts could be removed by mechanical scraping or by leaching with water and cultivation begun again as previously outlined.

## Conclusions

Both these alkali areas graphically display the hazards of over-irrigation using the furrow method of dispersion in a sandy soil. The hazard would not be nearly so great under humid conditions as there is not the concentration of salts in the profile that occurs in semi-arid or arid soils, extensive leaching processes having removed them. Also in clayey soils, as there is less seepage than in sandy soils, there is less tendency towards alkali accumulation, so that controlled furrow-irrigation is possible in these cases. If overhead irrigation, though certainly more costly, had been used in the two cases under discussion, the chances of alkali accumulation would not have been nearly so great, as the water is mostly conveyed in pipes or lined canals. Also, the soil is never saturated by overhead irrigation to the extent that it is by furrow-irrigation and a more strict control of the amount of water applied can be kept.

This contention is borne out by the fact that in the same area, a few miles distant from the alkali areas already discussed, overhead irrigation is practised on one farm, with no trace even of incipient alkalisation or salinisation. A test pit dug in an alluvial soil of much the same soil texture as T.P. 1630 A though somewhat finer, revealed no trace of salt accumulation to a depth of 6 feet. The irrigation water applied is the same in all cases.

The application of irrigation water by furrow methods is, however, not to be condemned in all instances. In humid areas under suitable conditions and even in some cases in semi-arid or arid areas, provided it is not grossly abused, it will be found eminently satisfactory, but in semi-arid or arid areas, especially on sandy soils, it should be practised with the utmost caution to avoid those harmful consequences that may follow its injudicious usage.

### Summary

The general causes of the development of alkali and saline soils are discussed and terminology defined. Physical and chemical analyses of alkali soil profiles from Heatonville, Zululand, as contrasted with a normal soil from the same district are tabulated and characteristics contrasted. The specific causes of the alkali development in these two occurrences are explained as being due to the artificial raising of the water-table, a factor induced by the injudicious application of irrigation water. Possible remedial methods of reclamation are advanced and a warning against injudicious irrigation sounded.

### Acknowledgements

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**Mr. Bentley (The Chairman),** thanked Mr. Maud for his paper and said this subject was of interest to everyone present concerned with producing cane. He said that Mr. Maud had mentioned the practice in Holland of flooding with fresh water on land that had been swamped by the sea. This had happened during the war, and he would like to know how they had managed to reclaim this land so quickly.

**Mr. Maud** said that as far as he understood they washed the land with fresh water and then planted those crops which were fairly resistant to salt. Conditions in Holland were somewhat different from the ones existing in the areas here he had written about. They were not brak soils but the damage had been done by sea water.

**Dr. Dodds** asked if there were any specific soil minerals which were most liable to form free sodium chloride on weathering. Furthermore was sodium the only offender in this respect? Could elements such as the alkaline earth metals like calcium or magnesium cause trouble, or would they be readily converted into relatively insoluble carbonates? In Puerto Rico on an area which is largely saline they could not grow most varieties of cane. They could however, he was told, grow Co.281. At Chirundu in Rhodesia he had seen alkaline and saline areas near the very top of a high bank alongside the Zambesi river. He was surprised at seeing the sugarcane in these areas so suddenly and severely affected. There were also bush areas further down the valley where only very few resistant species of plant would grow at all, mostly Mopani shrub.

**Mr. Maud** said that in this particular soil, calcium tended to be precipitated as calcium carbonate as was usually found in arid or semi-arid areas. He thought that the only minerals that could produce saline soils as found, would be the feldspars. The Beaufort soil had only recently been discovered in the sugar belt and he had not examined it microscopically to see which minerals it contained. One soil sample received at the Experiment Station from Triangle Estate in Rhodesia had a pH of 10 which was an extremely high value.

**Mr. du Toit** said the brak problem had occurred here and there in the sugar belt but in certain areas such as Pongola, appreciable areas were affected by brak. The possibility of this brak occurring in the newer areas of Swaziland, made any contribution on the subject of great value. At Pongola one planter had been very successful in reclaiming brak land by large applications of filter cake and drainage. He used 100 to 150 tons of filter cake per acre, and cane was being grown very successfully on these brak soils.