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Behaviour of Saline-Alkaline Punjab Soils Reclamation

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INTRODUCTION

The Punjab is an inland Province, some 750 miles away from the sea and is situated between 30° and 29.2° latitude in the Northern hemisphere. Its climate may be described as arid or semi-arid.

The soil of the Punjab plains which forms the Western end of the Indo-Gangetic valley, is alluvial in origin. The material produced by weathering of the rocks which is transported by water, or wind to low lying deprassions hundreds of miles away from the parent rock, contains, alongwith the mineral soil particles, stable salts of Calcium, Magnesium, Iron, Aluminium, Sodium and Potassium. The soil along with salts is deposited layer after layer forming a heterogeneous soil profile with respect to salt distribution These salts appear at the surface under the effect of natural agencies or as a consequence of human efforts to extract from the soil the food and fibre to meet with the requirements of mankind.

As in other parts of the Globe having similar climatic and rainfall conditions, agriculture in the plains of the Punjab (Pakistan) is beset with the twin problems of salinity and alkalinity of the soil.

Alkalization of soils has been discussed by various workers, for instance, deSigmond[1] in Hungary, Hilgard[2] and Kelley[3] in U.S.A., Hissink[4] in Holland, Gedroiz[5] in Russia and Asghar[6] in Pakistan. The fundamental changes involved in the process have been ascribed to the replacement of divalent ions with monovalent ions in the exchange complex. As a result of the changes the soil is rendered unfit for any agricultural use.

The Punjab Soils

Soil in the Punjab varies from place to place with regard to its mechanical composition, location of watertable, concentration of salts and

percentage of organic matter. A typical Punjab soil profile consists of alluvial deposits generally containing 10 to 15% of clay, 10 to 15 feet in thickness and overlying a sand stratum. The soil is generally of an alkaline reaction and contains sodium salts as well as exchangeable mono and divalent ions in the clay complex. It is generally calcareous and contains calcium carbonate mixed, as well as, in nodule form.

From the point of view of deterioration the Punjab soils can be divided into the following categories :—

(*i*) Sandy soils, deficient in clay as well as organic matter ;

(*ii*) Soils of waterlogged areas ;

(*iii*) Sandy loam soils, containing salts at variable depths in the soil profile ;

(*iv*) Clayey soils, with a high percentage of salts and high alkalinity ;

(*v*) Clayey soils, with high alkalinity but low salt content.

The alkaline soils of the Punjab in high watertable areas are discussed by Taylor, E.M., Puri A. N. and Asghar, A. G.[7] and a soil profile has been divided into the following layers :—

(*a*) an upper highly alkaline layer, compact and impervious ;

(*b*) a layer of medium alkalinity, containing calcium carbonate nodules ; and,

(*c*) a layer lower alkalinity and higher permeability than (*a*) and (*b*) above.

These three layers are usually found to be resting on sand strata.

The alkalization of soil, high in clay content, under deep watertable condition, renders the soil impervious to water and manifests phenomenon of mirage and gives a metallic sound on tapping.

Reclamation Method

In the Punjab like many other countries where primitive methods of agriculture are employed, the problem of salinity caused no alarm, so long as fresh areas were available for the farmer to shift cultivation. The cultivator was only driven to devise methods of tackling the problem of salinity when no fresh land was available for further shifting. The measures adopted and the methods tried by the tiller and the Soil Scientists[8] to reclaim the saline soils at one time or the other are :—

(*i*) Removal of surface salt deposit ;

(*ii*) Lowering toxic concentration ;

(*iii*) Change of crop pattern to resistant and tolerant plants.

(*iv*) Use of chemical amendments ;

(*v*) Addition of organic matter (green manuring)

(*vi*) Flushing of the soil and drainage ;

(*vii*) Combinations of the above methods.

(*i*) On analysis the soil scrappings was generally observed to be a mixture of sodium chloride and sodium sulphate. The method of removal of salt layer from the soil surface could be useful provided the salt existed only within the top soil but it is not the case and the incrustation at the surface if once removed is reformed in the very next season, because of the upward movement of salts from the lower layers.

(*ii*) The method of mixing of good soil or silt to lower the toxic concentrations of salts in the soil is not only a very temporary relief but also expensive.

(*iii*) Growing of salt or alkali resistant plants is very appealing to a casual observer but there is no economically sound and useful crop which can stand high salt concentration. After detailed investigations on various plants Hayward and Wadleigh[9] have graded the in the order of their resistance to salt. The work on alkali tolerance is still in the initial stages of study. Work on similar lines has been done in the Punjab for a few plants like Acacia-arabica (Kikar), Tamarix-articulata (Frash) Suaeda Fruticose (Lana), Atriplex Confortifolia (Lani), Ricinus-Cammunis (Castor), and Cynoden Dectylon (Dhub grass). Culturing such plants is, however, no solution of the problem.

(*iv*) The usefulness of applying chemical amendments, etc,, has been tried by various workers to liberate the harmful sodium ions from the soil complex. Such amendments cannot be applied on a large scale due to high cost.

The toxic effect of sodium salts, however, cannot be minimized by any known chemical amendments and a Chemist has yet to discover an economical method of preparing an insoluble sodium salt having low ionization value.

(*v*) Alakaline soils can be improved by green manures of various types and their usefulness in helping reclamation of such soils cannot be underrated.

(*vi*) The only measure which has been successful in removing salts from the soil is the use of excessive quantity of water to dissolve the salts and remove the salt solution through the subsoil to the water reservoir or through a drainage system to a natural outfall. This has been adopted in various countries as a general method of reclamation of saline or saline-alkaline soils with slight modifications in the technique to suit local conditions.

(*vii*) Sometimes one or two treatments described above are applied simultaneously to effect reclamation of saline or saline-alkaline soil.

In America, chemical amendments are generally applied simultaneously with leaching to remove sodium from the soil complex and then leaching the salts away with the leachate. Application of chemical fertilizers for crop production during and after reclamation is the rule. In Holland, in the highly salted land reclaimed from the sea, natural weeds and vegetation are allowed to grow for a few years, followed by pasture and later on normal crops are raised after heavy application of fertilizers. In the Nile Valley in Egypt again, large scale leaching followed by cropping has been the means employed for getting rid of salts. In the Punjab the special feature of reclamation of saline or saline-alkaline soils is the growing of a salt resistant crop requiring high delta of water like paddy or Sesbania Aculeata during the summer season. This is followed by a leguminous crop during the winter to compensate any loss of nitrogen that has occured due to excessive leaching.

In the case of alkaline soils again there is no basic difference in the techniques employed in different countries of the world tackling this problem. Replacement of exchangeable sodium with calcium sulphate, chloride or nitrate and subsequent removal of the sodium salts by leaching is the main object. In the absence of chemicals, green manuring has often been recommended. For very compact, hard alkaline soils, growing of long and strong rooted crops like Alfalfa and Egyptian Clover to open up the soil in the initial stages is resorted to.

A Reclamation Project for alkaline and saline-Alkaline Punjab Soils.

Patches of typically hard impermeable alkaline soil varying in size from a few acres to a few hundred acres are scattered over the Lower Bari Doab Colony, in the Punjab province irrigated by a canal carrying 4500 cusecs of water. There are some 40,000 acres of such land in this tract. It had defied all attemp's aimed at Colonization and its ownership vests in the Government. As soon as a successful technique for its reclamation was discovered a decade ago, it was decided to distribute this land on easy terms in small blocks to enterprising Colonizers.

The terms are :—

(1) The lease will be for a period of 6 years.

(2) The cultivator will faithfully carry out the directions of the Government in respect of the operations required in the land during the reclamation period.

(3) In case the cultivator is successful in reclaiming the land held by him to full productivity by the end of the stipulated term he will be entitled to become the owner of half of the land on payment of a nominal price which is about 1/6th, of the market value of cultivated colony land.

For reclamation purposes additional canal water is provided during the summer season at the rate of one cubic foot per second for 45 acres which

is about 6 times the normal allowance of water for cultivated land. The cultivator is required to level the fields, construct dykes for holding water in quarter acre plots and to apply water after every 7 days during the summer. He has to sow either paddy or the legume, Sesbanea Aculeate, during the summer, and irrigated Egyptian Clover or un-irrigated gram (Cicer Arietinum) during the Winter.

Where there is abundance of soluble salts in the soil in addition to high alkalinity paddy is grown during the first two or three years to wash away the salts, followed by deep rooted Sesbanea Aculeata. Where high alkalinity is manifested without high salts, the legume is introduced from the very beginning and paddy follows afterwards.

Two factors have contributed to the success with which this project has met. The sense of ownership in this country even for petty land holdings prompted the cultivators into exploiting the deteriorated land whole-heartedly. The method of reclaiming such land as outlined above is chemically, agriculturally and economically sound.

Limitation of Reclamation Projects.

The reclamation measures and schemes are no doubt successful to a great extent but there are certain limiting factors, some of these have a universal aspect while others are more or less peculiar to this country. Again, some of them have a human back-ground in which modification can be brought about, while others are of natural origin, which are either beyond one's control or point towards new lines of scientific research. The same are discussed below:—

Drainage. Drainage is the problem of all irrigated areas of the world and a pre-requisite of reclamation. The Punjab plains have a slope of 1 in 5000, in addition to an under-lain rocky-ridge in a North,—West and South-East direction, both of which factors are responsible for restricting sub-soil flow. Presence of efficient drainage system is essential for successful reclamation for all types of areas and more so, for areas with high or perched water-table. There is hardly any substantial addition to sub-soil reservoir due to reclamation activities with a permanent effect, yet in the absence of adequate drainage there is a temporary and local stagnation produced during paddy growing months, which is completely relieved during the following winter months. However, it forms part of the over-all problem of drainage of canal irrigated areas, and separate measures for this localized addition of water are not necessary.

Out of the various drainage methods tile-drainage has not found favour in this country for its high capital outlay and other hazards. Due to insufficient slope of the country boosting up would be necessary after every few miles in order to provide a suitable head. Open drainage is more practicable under Punjab conditions although its efficiency is limited in extent for discharge. It costs about 10% of the land. The future development of drainage appears to be in tubewell pumping, which is already making

headway An over-all drainage system under Punjab conditions would be open drainage coupled with tubewells where-ever necessary.

2. *Water Sources.* Although the Punjab has the finest and the most extensive net-work of canals in the world yet the duty of water in this province of Pakistan is about the highest. In other words there is too little water available for too much area and there are millions of acres of land waiting for irrigation facilities to be provided. Reclamation of deteriorated lands is an additional load on the already over-burdened water-resources. Although new Irrigation Projects are being explored, natural river supply is not a source to which it may be possible to look forward for unlimited help. Attention is, therefore, already being diverted to tapping of the under-ground water reservoir. The tubewells have, therefore, another good use of being a source of irrigation to make up the deeply felt water shortage.

3. *Apathy of the Cultivator.* The willingness and eagerness of the cultivator to break and cultivate the alkaline-saline soil referred to earlier is only a relative statement. On the one hand on account of his well known conservative traditions the cultivator of the Orient would not make sufficient preparation of his saline land for flooding, on the other he is tempted for his poverty as well as short-sightedness to utilize the water provided for flooding saline fields, in his already productive fields to get more and more out of them. Sub-division of holdings is another hurdle in organizing reclamation projects. A solution of these ills perhaps may now be sought in co-operative enterprise under the aegis of the Soil Reclamation Act recently promulgated by the Provincial Lagislature.

4. *Soil Fertility.* In Pakistan the fertilizer industry worth the name has yet to be established, the plant food reservoir in the soil is fast approaching exhaustion. Natural manures and green manuring are two expedients, which cannot cover all the land within reasonable time, and meet the requirements of the soil at the rate of which the soil reservoir is being depleted. In the case of saline and alkaline lands under flooding during reclamation, there is an additional drain on nutrients and as the soil is being freed from excessive salts and high alkalinity, it is also rendered poorer in plant food material. Nitrogenous fertilizers may meet with such deficiencies but their non-availability from local sources has made their utility as of limited value. Only in the quickest development of manufacture of chemical fertilizers within the country lies the solution.

5 *Permanency of Reclamation.* Taylor[10] contended that land once reclaimed was not liable to re-deterioration if the salts were removed beyond a 10′ depth because of the existence of a field capacity zone in between the pellicular zone and the capillary zone in the Soil Column. Asghar,[11] observed that upward movement of moisture is possible from depths greater than 10′ and a field moisture capacity zone cannot be maintained throughout the year under arid and semi-arid conditions. The possibility of re-deterioration of land after reclamation points to the necessity of evolving some

agricultural cropping and or soil management practices to check the re-appearance of salts on the surface.

6. *Rate of Reclamation and Soil Factors.* It has been observed that apart from the handicaps and short-comings mentioned in the foregoing the success of reclamation operation is largely governed bv the various soil characteristics. A study of such soil factors, which determine the rate of percolation of water to the subsoil has been made by Asghar, and co-workers (12). The variation in clay content, dry bulk density and pH value of the surface as well as subsoil horizon have been found to influence the removal of salt to an appreciable degree.

Object of Investigation.

In order to study the effect of various soil factors on the progress of reclamation, experiments were conducted on an Experimental-cum-Demonstration field research station, representing soils described under type 3 and 4 of Punjab Soils. This Research Station is situated in the District of Montgomery and is locally known as the Bhallewala Field Research Station. The area represents saline-alkaline soil types.

Experimental.

Soil Survey of the area was completed in the area during the year 1944 on the basis of one campling bore hole of 10 feet depth per acre. Soil samples from each foot were analysed for total soluble salts, pH value and mechanical composition. The soluble salt content of soil was determined by finding out the conductivity of 1 : 15 soil water suspension and converting the values into percentages on dry weight basis. The value of 0.2% is taken as the limit to distinguish saline from non-saline soils. The pH value was determined by the glass electrode method using the Bechman's pH meter-model H on 1 : 5 soil water suspension. A value of 8.5 or below is considered normal for Punjab soils, and higher values represent alkaline soils. The clay content was determined by Puri's Chaino-hydrometer method. The depth of the soil crust was also noted during the survey and the results are given in figures 1 and 2. It was observed that there is no variation of water table from field to field during the year but it rose from 30.4 feet in 1945 to 25.8 feet in 1950. The area was subjected to reclamation under cropping programme vide Table 8.

The reclamation operations were continued from 1944 to 1950 and observations were taken every year. Before commencing any reclamation operations in 1944 the area was divided into blocks of $1100' \times 990'$. A block of this size measuring 25 acres is known as a rectangle in the canal colonies. Each block was then divided into 25 one acre plots of $220' \times 198'$ and each plot into 4 sub plots of $110' \times 99'$. The final layout is shown in figure 3.

The seven factors examined which are considered to have a bearing on the rate of reclamation were as below :—

1. Thickness of the soil crust.
2. Clay content.
3. Initial degree of Hydrogen Ion Concentration.
4. Initial total solids content.
5. Delta of water applied during the reclamation operations-leaching.
6. The organic matter content of the soil-green manuring.
7. Continuity of cropping, cultivation and fallowing.

Tables 1 to 6 show the progress of reclamation in 6 typical plots Plots 40/1 and 40/17 (Tables 1 and 2) represent a soil crust 6 feet or less in thickness. They have both a medium clay content and pH values below 9.0. The variable factor in these two profiles was the salt content. Plots 40/23 and 40/24 have a medium crust of 6 to 10′ thickness. They have the pH values ranging upto 9.0 and a salt content of about 1.5%. In this case the variable is the clay content. Plots 51/1 and 51/20 have a thick soil crust of 10′ or more, a medium clay content, and a salt content of the order of 1% while the pH range showed a marked difference between these two profiles.

The clay content was lowest in plot 51/20 being under 15%, and highest in 40/23 being above 18%, while the clay content of the remaining 4 plots 50/1, 40/24, 40/1, and 40/17 was in the range 15 to 16%. The initial pH values were highest in 51/20 (above 10), high in 50/1, 40/23, 40/24 and 40/17 (near 9.0) and about normal (8,5) in 40/1. The salt content was near 1% in 50/1, 51/20 and 40/1 and between 1.5 and 2.0% in the other 3 plots.

Tables 1 to 7 show the variations in soil factors and table 8 the variations in treatment. The variable soil factors are thickness of the soil crust, clay content, initial degree of salinity and the initial degree of alkalinity. The variations in treatment are :—

(*a*) Delta of water applied,

(*b*) Organic matter content, and,

(*c*) Continuity of cropping.

A few comments on these last mentioned three variable factors will be helpful.

(*a*) Delta of water applied

Surplus water is available in the Punjab rivers with the melting of snow in the mountains from April to September. A water allowance of one

second foot for every 45 acres of deteriorated land is usually made for fields to be put under reclamation, and every field gets a fixed turn every 5th or 7th day. This gives approximately 100 acre inches of water for each field during the six summer months. However, there are seepage losses and occasional canal closures and 70 to 75 acre inches is a more correct average for the delta of water applied, This is applied in a total of 20 to 25 irrigations of 3 to 4 inch depths. This rice crop is transplanted from about the middle of June and Sesbania about the same time. Till the crop is put in, water is applied regularly to the fields for leaching down the salts. This preliminary leaching reduces the concentration of salts in the soil and enables the crop to establish. The number of rice or sesbania crops is generally mentioned to express the delta of water applied for purposes of reclamation.

(*b*) **Organic matter.**

The variations in the organic matter content are important to account for the variations in crop yields due to the presence or deficiency of plant nutrients in the soil. The measure adopted to increase the organic matter content of the soil is green-manuring, as Farm-yard manure is not available in sufficient quantity for large areas. In the process of decay of the organic matter added as green manure, the organic acids produced react with the soil colloids and help liberate the alkaline sodium ions from the clay complex and to convert sodium clay into calcium clay.

(*c*) **Continuity of cropping**

Continuity of cropping is important from the point of view of reclamation in that a vegetative covering on the soil surface reduces surface evaporation of moisture and hence slows the capillary movement of salt bearing water. Thus when a field is kept fallow the salts have greater tendency to move from lower depths to the surface.

Progress of reclamation

The progress of reclamation in the profiles under observation may now be studied at different stages with reference to the soil factors and the variations in treatment discussed earlier.

After one summer season.

There was a decrease in the salt content in Plot 40/1 in the upper 6 feet, a slight increase in lower depths upto 10′ and net decrease of 0.45% in the whole profile. There was a rise in the pH values in the upper two feet, the maximum in the first foot. This may be due to the heavy reduction in the salt content and consequent hydrolysis of sodium ions in the absence of abundance of salts. It has been observed[13] that when saline soils are afforded facility to undergo base-exchange reaction as a result of hydrolysis under excessive moisture, they tend to assume pH value of 9 which may be considered as a stable state of alkalinity for saline soils. A rise in pH value after leaching is also known to occur due to the determinate pH value being depressed in the presence of salts in the soil solution and registering a rise with the removal of salts.

More or less similar reduction in the salt content and rise in pH values occured in the profile of plot 40/17. The reduction in the salt content is 0.68% in the case of plot number 40/17 as compared with 0.45% in 40/1 but this is due to the higher initial total salt content.

In the case of the profile of plot 40/23 there was decrease in the salt content in the upper three feet and at 5th and 7th feet depths. There was an increase in the 4th foot and the soil of remaining depths did not show any reduction. An average decrease of 0.33% in the whole profile was observed. A fall in pH value in the soil of 2nd, 3rd, 4th and 8th to 10th foot depths was also noticed. Rest of the profile showed a very slight change in this respect.

In this profile of plot 40/24, the salt content decreased upto 5 feet depth and increased in the lower 5 feet. The average decrease was 0.2% for the whole profile. The pH values showed a tendency to rise in places of low alkalinity and to fall where it was high.

It is observed that decrease in salt content is more regular in the case of 40/24 than 40/23. This may be due to lower values cf clay content in plot 40/24 as lower clay content means greater percolation. The lower overall decrease inspite of a lower clay content may be attributed to the thicker soil crust of 40/24 than that of 40/23 by at least one foot.

A comparison between the two profiles with a thin crust and the two with a thicker crust also, shows that the quantity of salts removed is more and in other words the rate of reclamation is better in the two profiles with the soil crust of 6 feet or less than in the other two with the thicker soil crust.

After three summer seasons

There was a complete removal of excess of salts throughout the profile of 40/1 and a consequent rise in the pH values except in the first foot depth in which there was a decrease, The plot was green manured in the last summer season and the effect of this did not go below the first foot as the green matter was buried within the first foot depth. In the profile 40/17 a decrease in the salt content throughout the 10 feet depth was observed except in the 5th foot in which there was a slight increase. Except in the first foot the salt content was above 0.2% throughout There was a fall in the pH values due to the action of carbon dioxide produced by the roots of crops. The reduction in the salt content in the case of 40/17 during the 3 years period was 1.38% against 0.97% in 40/1 but salts were in excess in the same profile as compared to 40/1 in which salts were reduced below the permissible limit throughout the profile. Both the differences are accounted for by its higher initial salt content. Berseem was sown in plot 40/17 in the winter season preceding the third rice crop and although it was not successful the waterings given may have caused a part of the total reduction in salt content.

Comparing profile 40/23 with 40/24 both the profiles were reclaimed almost simultaneously except for the excess in the first foot in 40/23 which

would be due to the higher clay content of this profile. The rate of reclamation was no doubt increased as a result of putting in Berseem (Egyptian Clover) during the 2nd winter season. A marked fall in pH value in the first foot depth in 40/23 which was above 9.5 after the first summer season was noticed. Some-what similar decrease in pH value took place in the 9th foot where it had been near pH 9.0 after the first summer season. In all the other depths where it was below 9 0 the pH value increased. The net result was an increase in the mean pH value of the upper 5 feet. A similar decrease and increase towards pH value of 9.0 occured in the case of the profile of plot 40/24 but in this case the net result was a decrease in the mean value for the upper 5 feet. This difference is due to the higher clay content of 40/34 and the higher base exchange capacity resulting therefrom.

Among the soil profiles with more than 10 feet thickness of soil crust the profile 50/1 having a lower pH value showed a decrease in the salt content throughout the profile and only in the 9th foot it was above 0.2% after the 3rd rice crop. There was also a decrease in the pH values throughout the profile except in the first foot. In the case of 51/20 which had very high initial pH values throughout the profile the decrease in the salt content is only 0.26% from the initial as compared to 0.67% for 50/1. The pH values also did not show a decrease particularly in the upper 4 feet in which there was in fact a slight increase. This low rate of reclamation in this case is evidently due to the very low permeability of this profile where leaching down of salts was very slow and the crops sown invariably failed which may have helped in lowering the pH values in the profile of 50/1.

Comparing the profiles with thin, medium and thick soil crust with each other, it was observed that the rate of reclamation was inversely proportional to the thickness of the soil crust with the exception of profile 40/17 which had a thin soil crust but the highest salt content, and of profile 51/20 with the highest pH values which had, therefore, developed a high degree of impermeability.

After 5 summer seasons.

There was an appreciable fall in the pH values in plot 40/1 as compared with the results obtained two years earlier, and a noticeable increase in salt content which is due to the sodium ions liberated from the clay complex as indicated by the fall in pH values.

The analysis results of 40/17 show a slight increase in the salt content as well as the pH values. The salt movement appears to have acquired an upward trend whereby the salt content has decreased in the lower depth and increased in the upper 4 feet. This appears to be due to wheat crops having been subtsituted for berseem in the winter in the last 2 years. Berseem gets copious watering while wheat is a low delta crop. The slight increase in pH value is also manifested.

In the cases of 40/23 and 40/24 a fall in pH values and an increase in the salt content throughout the soil profile as result of decrease in the alkaline reaction was observed, but the increase in the salt content in 40/23 is out of proportion and would appear to be due to change in sampling site.

The analytical results for 51/20 indicate a fall in mean pH value to the extent of 1.16 and an increase in the salt content by 0.14%. This is explained by the fact that the plot was put under leguminous crops during the previous four seasons and was green manured once. The organic acids and carbon dioxide thus released reacted with the soil complex thereby lowering the pH value. The sodium salts released from exchange complex were removed by leaching leaving a slight excess.

AFTER 7 YEARS SUMMER SEASONS

The changes in the profile of 40/1 after a further period of two years do not appear to be significant. However, the salt content was reduced still further while the pH values registered a slight rise. In 40/17 there was a further lowering of salt content as well as pH values, the latter as a result of the green manuring done in the previous year.

In 40/23 and 40/24 there is a decrease in the salt content and an increase in the pH value as in the case of 40/1. This increase in pH values is due to a tendency in Punjab soils to show a rise in pH values where initial pH value is lower than 9.0 and to register a fall where it is higher. The profile 50/1 has also been reclaimed both in respect of salt content and alkalinity. Plot 51/20 also shows a decrease in the salt content as well as alkalinity but the salt content is still slightly higher than the permissible limit and the pH values have come down to near normal in the upper two feet. The reduction in the salt content was achieved by re-introducing rice and the reduction in pH values was made possible by establishing the crops there.

Variations in Treatment.

The role of the various soil factors in the rate of reclamation and of variations in treatment particularly of those in the delta of water applied and the organic matter content has been noticed in some detail in the foregoing paragraphs and it is felt that soil factors play a predominant part on the progress of reclamation of saline/alkaline soils. But since the variation in treatment has also influenced the rate of progress of reclamation it would, therefore, be desirable to re-examine the position with regard to the variations in treatment.

Leaching.

It has been observed in the case of plot 40/17 that in the 4th and 5th winter seasons replacing the high delta crop of Berseem by the low delta crop of wheat resulted in an upward movement of salts in the profile In 51/20 the rate of reduction of salt content has accelerated with the re-introduction of rice crop. Similarly in the case of plot number 40/17 the irrigations applied to Berseem crop in the 2nd and 3rd years has caused the removal of a higher percentage of salts from the soil profile, although in this case the high salt content of the profile itself must also have been a contributing factor.

Organic Matter Content and Green Manuring.

In the course of the 7 years period, plot 40/1 was green manured once in the 3rd summer season, and plot number 40/17 was green manured twice in the 4th and 6th years respectively. As a result the pH values in the latter case are lower at the end of the period whereas the position was reverse in the beginning.

All the other plots received one green-manuring treatment during this period. It is observed that there is an appreciable rise in the yield of crops following green manuring and this is expected as a natural consequence of the addition of organic matter in a barren alkaline-saline soil which had not borne vegetation for long periods and which has subsequently been subjected to heavy leaching operations.

Continuity of Cropping.

All the plots under observation were cropped more or less continuously during the seven years period with few exceptions. The vacant season for plots 40/1 and 40/17 occurred at the very end of the period. However, it may be expected that if a fallow season was not allowed the salt content would not have remained higher than that of 40/23 and 40/24 particularly in the case of 40/17.

Discussion of Results.

1. The progress of reclamation of profiles representing widely varied soil conditions has shown that the rate of reclamation is affected adversely by the thickness of the soil crust, the clay content of the soil, the initial salt concentration and the initial degree of alkalinity because with higher values of these constants the rate of progress of reclamation was slower. It has also been observed that the rate of reclamation is favourably influenced by increasing the quantity of water applied for reclamation and the amount of organic matter added to soil during the period of reclamation. It has further been observed that in any particular profile a favourable soil factor present may be prevented from increasing the rate of reclamation by one or more unfavourable soil factors. It follows from this that if simultaneous reclamation of a number of fields is required then the effect of unfavourable factors should be controlled by suitable modifications of the method of reclamation vis by growing winter crops like Berseem requiring high irrrigation delta in fields having higher salt content than other, or green manuring in excessively alkaline fields.

2. Consequently grading of fields according to the soil factors will always be helpful before taking up reclamation. The profiles which have been examined can be placed in the following grades :—

GRADE I

Thin soil crust, medium clay content, pH below 9.0, salt content 1.0% to 1.5%.

GRADE II

Medium soil crust, medium to high clay, pH below 9.0, salt content 1.0 to 1.5%.

GRADE III

Soil crust thin medium or thick, pH below 9, medium clay, salt content 1.5% to 2.0%.

GRADE IV

Thick soil crust, medium to high clay content, pH above 9.5, salt content upto 1%.

The period required for reclamation has been found to vary widely. In plots in grade I, the excessive salts have been removed with three high delta crops, and pH value reduced to normal after 5 years with one green manure crop, The plots in grade II were reclaimed from excess of salts in 3 years with 3 rice crops and two Berseem crops and the pH values were reduced to normal with 5 years cropping including one green manure crop. The soil in grade III was reclaimed in 5 years after 3 rice crops, 2 Berseem crops, 2 summer green manured crops and one summer leguminous crop. The plot in grade IV had high pH values and slight excess of salts even after 5 rice crops, one green manure crop and one summer leguminons crop. These observations show that to reclaim different grades of soils within the same period it is necessary that suitable measures be taken for the purpose, which may include green manuring of leguminous crops, if alkalinity persists or increasing the number of high delta crops, when the salt concentration is still above 0.2% . Grading of soils on the basis suggested is bound to be helpful in finding before hand the difficulties likely to arise in achieving reclamation within a prescribed period. Thus it is possible to find out the period or the treatment required for reclamation of a particular soils in the alkaline region of Punjab before commencing reclamation.

Quantitative reduction in salt content.

A quantitative idea of the removal of salts at different stages under variable conditions will no doubt be found interesting and helpful. With one rice crop the average decrease in salt content effected was 0.41% for 3 profiles representing thin and medium soil crust, medium clay content, with pH values below 9.0 and salt content varying from 1% to 2%.

With 3 rice crops without winter irrigation the average reduction in salt content was 0.82% for 2 profiles varying from thin to thick soil crust, low to high pH values and with medium clay content. With 3 rice crops supplemented with one Berseem crop in 3 profiles representing different conditions of soil crust, clay content and salt content the average reduction in 3 years was 1.39%. If the rice crop is taken to account for about 0.4% reduction in one season the balance of about 0.2% is on account of the Berseem crop.

For a single profile with very high p'H va'ues the reduction effected by 3 rice crops was only 0.2%.

Crop yields.

A study of the rate of reclamation is incomplete without reference to crop yields as the object of reclamation is to raise successful crops. In the case of the profiles studied it is noticed that the crop yields increased from zero in the first season as the reclamation operations progressed but when the salt content had been reduced to normal the yields were still below normal and the tendency is for the yields to be stationary except when green manuring has been done. This indicates that the soil is deficient in plant food ingredients due to the land having remained devoid of vegetation and on account of the plant food removed by the excessive leaching given for reclamation. The addition of plant food to the soil by green manuring by application of farm-yard-manure and chemical fertilizers during and after reclamation is to be considered as a part of reclamation without which high crop yields cannot be obtained.

Summary.

(*i*) The general characteristics of saline, alkaline-saline, and alkaline soils met with in the Punjab Province of Pakistan and measures undertaken for utilisation of such lands for normal crops production have been discussed. It has been brought out that the basis of control measures being practised in different countries of the world are identical.

(*ii*) The methods so far practised for reclamation of deteriorated soils have been discuussed and it has been explained that for salinity the only effective and practicable measure is flooding and drainage, while for alkalinity the application of chemicals for replacing sodium ions from the clay complex by calcium is entirely effective. The organic acids produced during decay of green manures serve the same purpose.

(*iii*) Limitations of reclamation projects with special reference to the Punjab (Pakistan) conditions and the directions in which modifications in favour of reclamation are needed or are taking place have been indicated.

(*iv*) It has been shown that besides the man-made bottle-necks and other factors which are susceptible to modifications there are certain natural factors and soil characteristics which either promote or retard the progress of reclamation. These factors are :—

1. Thickness of the soil crust.
2. Clay content.
3. Initial degree of alkalinzation.
4. Initial total solids content.

It has been observed that the rate of reclamation of a saline soil is adversely effected by each of these factors. The first three of these factors have simllar effect on the rate of reclamation of alkali soils but in this case the presence of salts facilitated reclamation operation.

(*v*) The effect of varying treatments given to soils under reclamation has been examined and it has been shown that the rate of reclamation is favourably affected by the following:—

1. Delta of water applied for flooding.
2. Organic matter content of the soil.
3. Continuity of cropping and cultivation.

(*vi*) It has been shown that in order to achieve simultaneous reclamation of profiles representing widely varied soil condition, grading of the profiles is necessary and the treatments to be applied should be according to the requirements of various grades. With the help of such grading it is possible to predetermine the treatment and the period of operations of reclamation of different types of soils.

(*vii*) Quantitative determination of the salts removed by leaching has been illustrated and such determination can be helpful in estimating the delta of water required for reclamation of a given soil.

(*viii*) It has been noticed that although the crop yieldes increase with advancement of reclamation but normal crop yields cannot be obtained without application of organic or inorganic manures-farm yard manure and green manuring or chemical fertilizer. It has been emphasised that addition of manures should form an essential part of reclamation operations.

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TABLE No. 1

ANALYSIS RESULTS OF SOIL SAMPLES PERTAINING TO PLOT NUMBER 40/1.

Depth.	Clay	Initial.		After Summer 1944		After Summer 1946		After Summer 1948		After Summer 1950	
		pH	T. S	pH	T. S	pH	T. S.	pH	T. S	pH	T. S
1	2	3		4		5		6		7	
0—1′	18.0	8.00	1.54	9.94	0.24	9.82	.15	8.35	.23	8.65	.11
1—2′	18.4	8.35	1.83	8.82	0.29	9.49	.13	8.35	.22	8.68	.11
2—3′	15.0	8.55	1.30	8.60	0 66	0.02	.12	8.38	.24	8.70	.10
3—4′	17.4	8.50	1.23	8.60	0.56	8.80	.12	8.36	.19	8.62	.11
4—5′	15.0	8.94	1.23	8.52	0.47	8.70	.11	8.43	.21	8.70	.11
5—6′	8.4	8.66	0.67	8.52	0.62	8.72	.12	8.57	.20	...	.12
6—7′	9.5	8.58	0.88	8.56	0.90	8.73	.11	8.41	.14	...	.12
7—8′	9.5	8.78	0.85	8.71	0.70	8.70	.12	8.65	.17	...	.12
8—9′	12.4	8.70	0.72	8.60	1.20	8.78	.11	8.39	.22	...	.13
9—10′	8.2	8.70	0.71	8.58	0.78	8.93	.12	8.51	.26	...	.13

TABLE No. 2

ANALYSIS RESULTS OF SOIL SAMPLES PERTAINING TO PLOT NUMBER 40/17.

Depth.	Clay	Initial.		After Summer 1944		After Summer 1946		After Summer 1948		After Summer 1950	
		pH	T. S	pH	T. S	pH	T. S	pH	T. S	pH	T. S
1	2	3		4		5		6		7	
0—1′	20.0	9.65	1.40	9.88	0.36	9.48	.19	9.70	.46	8.70	.11
1—2′	15.2	8.78	2.20	9.22	1.15	9.09	.26	8.52	.48	8.82	.14
2—3′	15.9	8.73	1.52	8.50	2.11	8.49	.28	9.50	.32	8.48	.17
3—4′	16.0	8.61	2.15	8.50	1.70	8.49	.24	8.38	.65	8.50	.16
4—5′	16.4	8.66	2.80	8.69	1.00	8.09	1.04	8.19	.96	8.52	.14
5—6′	15.2	8.70	2.50	8.70	.92	8.04	.64	8.22	.35	...	.15
6—7′	10.1	8.65	1.60	8.58	1.00	8.12	.48	8.00	.36	...	.25
7—8′	7.0	8.63	0 67	8.43	.95	8.19	.42	8.08	.29	...	.30
8—9′	8.4	8.10	1.80	8.32	1.00	8.36	.41	8.28	.25	...	,31
9—10′	7.0	8.75	1.80	8.28	1.41	8.30	.71	7.87	1.02	...	.35

TABLE No. 3

ANALYSIS RESULTS OF SOIL SAMPLES PERTAINING TO PLOT NUMBER 40/23

Depth.	Clay	Before Recl: 1943		After Summer 1944		After Summer 1946		After Summer 1948		After Summer 1950	
		pH	T. S	pH	T. S	pH	T. S	pH	T. S	pH	T. S
1	2	3		4		5		6		7	
0—1′	19 2	9.58	1.31	9.54	.20	8.78	.24	9.01	.16	8.52	.14
1—2′	17.5	8.98	1.54	8.52	.70	8.84	.17	8.28	.31	8.60	.11
2—3′	17.0	8.78	1.59	8.49	1.22	8.81	.11	8.13	1.15	8.62	.11
3—4′	17.6	8.90	1.35	8.37	2.11	8.62	.13	7.89	.97	8.55	.10
4—5′	15.5	8.48	2.05	8.51	2.00	8.72	.12	8.10	.42	8.40	.12
5—6′	23.3	8.40	2.40	8.51	1.81	8.60	.13	7.94	.33	...	.12
6—7′	14.7	8.50	2.40	8.56	1.25	8.58	.17	7.92	.45	...	.13
7—8′	8.9	8.80	1.06	8.49	1.05	8.53	.14	8.28	.44	...	.4
8—9′	9.0	9.08	.60	8.90	.65	8.64	.13	8.21	.49	...	.12
9—10′	9.2	9.71	.72	8.76	.69	8.80	.10	8.28	.36	...	.11

TABLE No. 4

ANALYSIS RESULTS OF SOIL SAMPLES PERTAINING TO PLOT NUMBER 40/24

Depth.	Clay	Before Recl: 1943		After Summer 1944		After Summer 1946		After Summer 1948		After Summer 1950	
		pH	T. S	pH	T. S	pH	T. S	pH	T. S	pH	T. S
1	2	3		4		5		6		7	
0—1′	10.7	9.12	1.60	8.60	.28	8.82	.09	8.19	.29	8.45	.12
1—2′	17.8	8.71	2.10	8.28	.45	8.53	.19	8.08	.24	8.40	.14
2—3′	16.9	8.67	2.35	8.70	.55	8.61	.14	8.19	.16	8.50	.12
3—4′	15.4	8.65	1.80	8.81	.85	8.70	.09	8.29	.14	8.52	.12
4—5′	15 6	8.50	1.70	9.40	1.35	8 58	.11	8.21	.15	8.80	.12
5—6′	17.6	8.38	2.00	9.22	2.10	8.54	.14	8.32	.19	...	.12
6—7′	16.8	8.60	1.60	9.28	2.40	8.54	.14	9.21	.16	...	.12
7—8′	13.6	9.05	1.10	9.61	1.81	8.48	.19	9.54	.19	...	.13
8—9′	9.4	9.62	.66	10.14	2.00	8.51	.14	9.63	.28	...	.16
9—10′	9.6	9.60	.70	10.35	1.81	8.61	.13	9 57	.20	...	.18

TABLE No. 5

ANALYSIS RESULTS OF SOIL SAMPLES PERTAINING TO PLOT NUMBER 50/1.

Depth.	Clay	Before Recl. 1943		After Summer 1944		After Summer 1946		After Summer 1948		After Summer 1950	
		pH	T. S	pH	T. S	pH	T. S.	pH	T. S	pH	T.S.
1	2	3		4		5		6		7	
0—1′	15.8	8.80	1.02	...	...	8.90	.15	...	...	8.28	.14
1—2′	15.0	8.80	.94			8.70	.19			8.22	.14
2—3′	14.3	8.88	.91			8.73	.20			8.25	.14
3—4′	13.2	9.80	.73			8.88	.10			8.20	.14
4—5′	15.7	10.10	.74			8.73	.17			8.20	.13
5—6′	16.3	10.02	.90	Not available	Not available	8.73	.15	Not available	Not available	...	.15
6—7′	15.6	10.03	.74			8·60	.16			...	.13
7—8′	16.7	10.01	.90			8.83	.14			...	.14
8—9′	15.9	10.10	.85			8.42	.30			...	.12
9—10′	15.8	10.02	.74			8.60	.16			...	.13

TABLE No. 6

ANALYSIS RESULTS OF SOIL SAMPLES PERTAINING TO PLOT NUMBER 51/20.

Depth.	Clay	Before Recl. 1943		After Summer 1944		After Summer 1946		After Summer 1948		After Summer 1950	
		pH	T. S	pH	T. S	pH	T. S.	pH	T. S	pH	T.S.
1	2	3		4		5		6		7	
0—1′	10.8	9.22	1.57	...	...	9.54	0.34	9.60	.25	8.55	.16
1—2′	15.9	9.71	1.27			10.00	0.35	9.60	.48	8.80	.18
2—3′	15.0	9.89	1.13			10.09	0.37	9.81	.58	9.95	.19
3—4′	13.1	10.00	1.00			10.10	0.49	9 81	.88	10.10	.24
4—5′	13.1	10.03	0.68			9.98	0.86	9.73	.99	10.15	.26
5—6′	18.3	10.03	1.10	Not available	Not available	9.91	1.18	9.71	1.10	...	.28
6—7′	19.0	10.10	1.04			9.84	1.51	9.68	.71	...	.29
7—8′	16.8	10.20	.86			9.98	1.19	9.68	1.25	...	.27
8—9′	18.0	10.20	1.05			9.98	9.96	9.71	1.73	...	.29
9—10′	16.8	10.26	0.95			10.08	0.74	9.80	1.49	...	.38

TABLE 7

SHOWING VARIATIONS IN SOIL FACTORS AT DIFFERENT STAGES

(Average of values for 10′ 5′ and 6′ depths for salt content, PH value and clay content respectively.)

Plot	Crust	Clay	Initial		After summer 1944		After summer 1946		After summer 1948		After summer 1950	
			pH	T. S.	pH	T. S.	pH	T. S.	pH	T. S.	pH	T. S.
1	2	3	4		5	6	7	8	9	10	11	12
40/1	0—6′	15.37	8.47	1.09	8.89	.64	9.17	.12	8.37	.21	8.67	.11
40/17	0—6′	16.45	8.89	1.84	8.96	1.16	8.73	.46	8.86	.51	8.60	.21
40/23	6—10′	18.35	8.94	1.50	8.69	1.17	8.75	.14	8.28	.51	8.54	.12
40/24	6—10′	15.67	8.73	1.56	8.76	1.36	8.65	.13	8.19	.20	8.47	.13
50/1	10—	15.05	9.28	.84	Not	avail-able	8.80	.17	Not available	...	8.23	.14
51/20	10—	14.37	9.77	1.06	Not	avail-able	9.94	.80	9.71	.95	9.51	.25

TABLE No. 8

SHOWING THE YIELD IN POUNDS PER ACRE OF DIFFERENT CROPS FOR VARIOUS SEASONS FROM THE EXPERIM

Plot	1944				1945				1946				1947				1948			
	Summer		Winter		Summer		Winter		Summer		Winter		Smmer		Winter		Summer		Winter	
	Crop	Yield	Crop	Yield	Crop	Yield	Crop	Yield	Crop	Yield	Crop	Yield	Crop	Yield	Crop	Yield	Crop	Yield	Crop	Yield
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
40/1	Rice	82	Gram	Nil	Rice	82	Gram	328	Jantar Green Manure	Nil	Wheat	697	Jantar	574	Wheat	574	Mash	615	Wheat	492
40/17	Rice	Nil	Gram	Nil	Rice	Nil	Berseem	Nil	Rice	660	Berseem	Nil	Jantar Green Manure.	Nil	Wheat	492	Mash	656	Wheat	410
40/23	Jantar 4—0	328	Gram	Nil	Rice	582	Berseem	Nil	Rice	Nil	Berseem	Nil	Jantar Green Manure.	Nil	Wheat	328	Mash	1,086	Wheat	246
40/24	Jantar 4—0	Nil	Gram	90	Rice	147	Berseem	5,658	Rice 4—0 Nursery 4—0	61	Berseem	Nil	Jantar Green Manure	Nil	Wheat	492	Mash	1,176	Wheat	492
50/1	Rice	Nil	Nil	Nil	Rice	Nil	Gram	...	Rice	82	Gram	Nil	Jantar	332	Vacant	Nil	Jantar (Seed)	86	Lentil	410
50/20	Rice	Nil	Nil	Nil	Rice	Nil	Gram	Nil	Rice	Nil	Gram	Nil	Jantar Seed.	117	Wheat kanal 6—0 Lentil 72 kanal 2—0	164	Jantar Green Manure	Nil	Lentil	328

PAPER No. 311

TABLE No. 8

/ING THE YIELD IN POUNDS PER ACRE OF DIFFERENT CROPS FOR VARIOUS SEASONS FROM THE EXPERIMENTAL PLOTS.

		1946				1947				1948				1949				1950			
Winter		Summer		Winter		Smmer		Winter		Summer		Winter		Summer		Winter		Summer		Winter	
›p	Yield	Crop	Yield	Crop	Yield	Crop	Yield	Crop	Yield	Crop	Yield	Crop	Yield	Crop	Yield	Crop	Yield	Crop	Yield	Crop	Yield
3	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
ım	328	Jantar Green Manure	Nil	Wheat	697	Jantar	574	Wheat	574	Mash	615	Wheat	492	Cotton	475	Berseem	1,148	Vacant	Nil	Wheat	1,394
ɛem	Nil	Rice	660	Berseem	Nil	Jantar Green Manure.	Nil	Wheat	492	Mash	656	Wheat	410	Jantar kanal 4—0 G. M. kanal 4—0 Bajra R. A. 4—0	3280	Wheat Gram.	369 574	Cotton kanal 4—0 Vacant 4—0	551	Fodder	Sold
ɛem	Nil	Rice	Nil	Berseem	Nil	Jantar Green Manure.	Nil	Wheat	328	Mash	1,086	Wheat	246	Chari Guara Fodder	12300	Wheat	779	Cotton	812	Fodder	5,034
ɛem	5.658	Rice 4—0 Nursery 4—0	61	Berseem	Nil	Jantar Green Manure	Nil	Wheat	492	Mash	1,176	Wheat	492	Mash Fodder	12,050	Wheat	1,148	Cotton	697	Fodder	5,084
ım	...	Rice	82	Gram	Nil	Jantar	332	Vacant	Nil	Jantar (Seed)	86	Lentil	410	Jantar Green Manure	Nil	Wheat	492	Mash	225	Gram	492
ım	Nil	Rice	Nil	Gram	Nil	Jantar Seed.	117	Wheat kanal 6—0 Lentil 72 kanal 2—0	164	Jantar Green Manure	Nil	Lentil	328	Rice	246	Gram 6—0	287	Rice 4—0 Fodder. 4—0	139 1,640	Gram	328

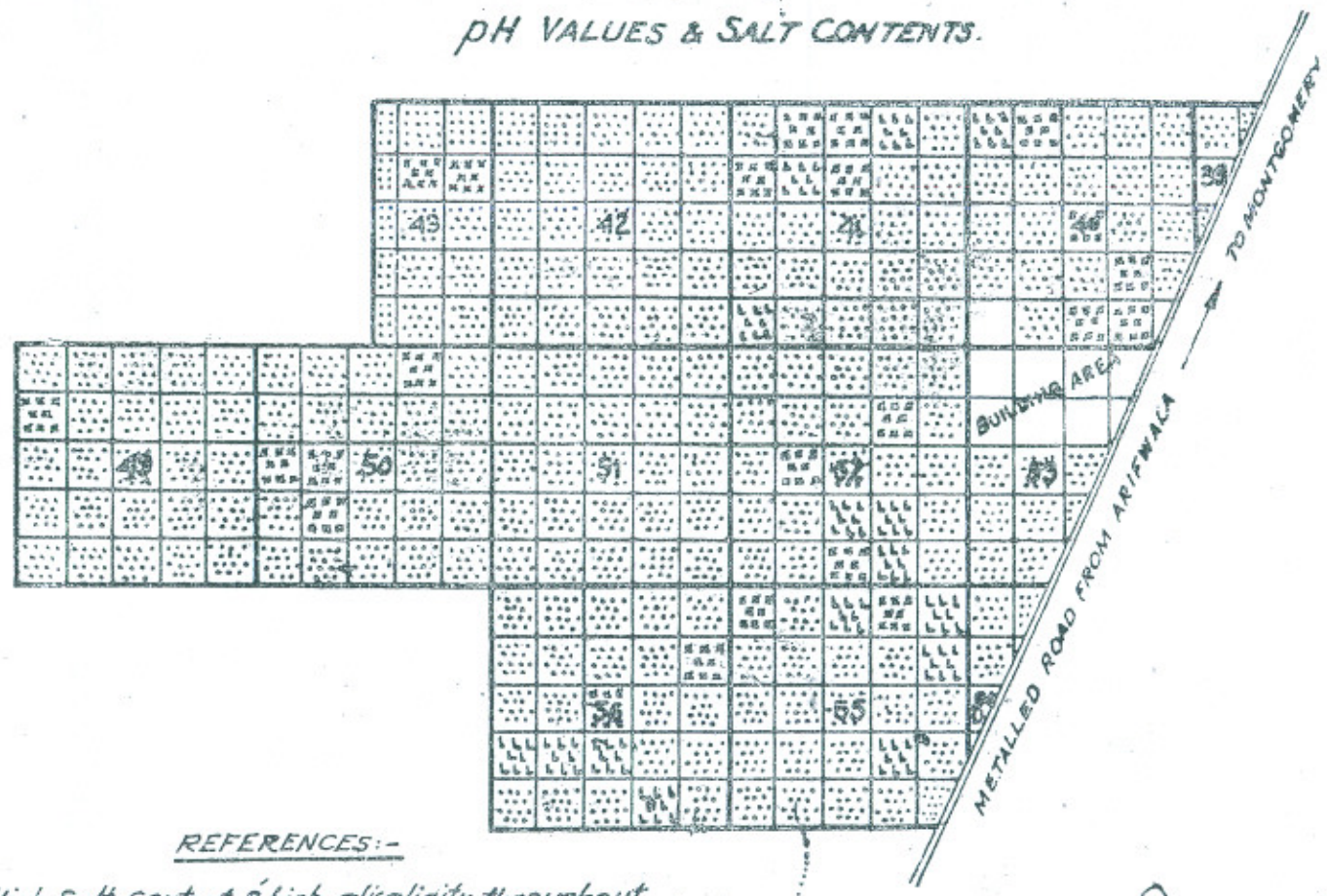
FIG: 1.

PAPER NO 311

BHALLEWALA EXPERIMENTAL RECLAMENTAL STATION

SHOWING

pH VALUES & SALT CONTENTS.



REFERENCES:-

(i) High Salt Content & high alkalinity throughout the Soil Profile.....

(ii) High Salt Content throughout the Soil Profile and High, Alkalinity at the Surface (within Upper 2).....

(iii) High Salt Content throughout the Soil Profile and less Alkalinity at the surface.

G. Ghasghar

DIRECTOR LAND RECLAMATION

PUNJAB

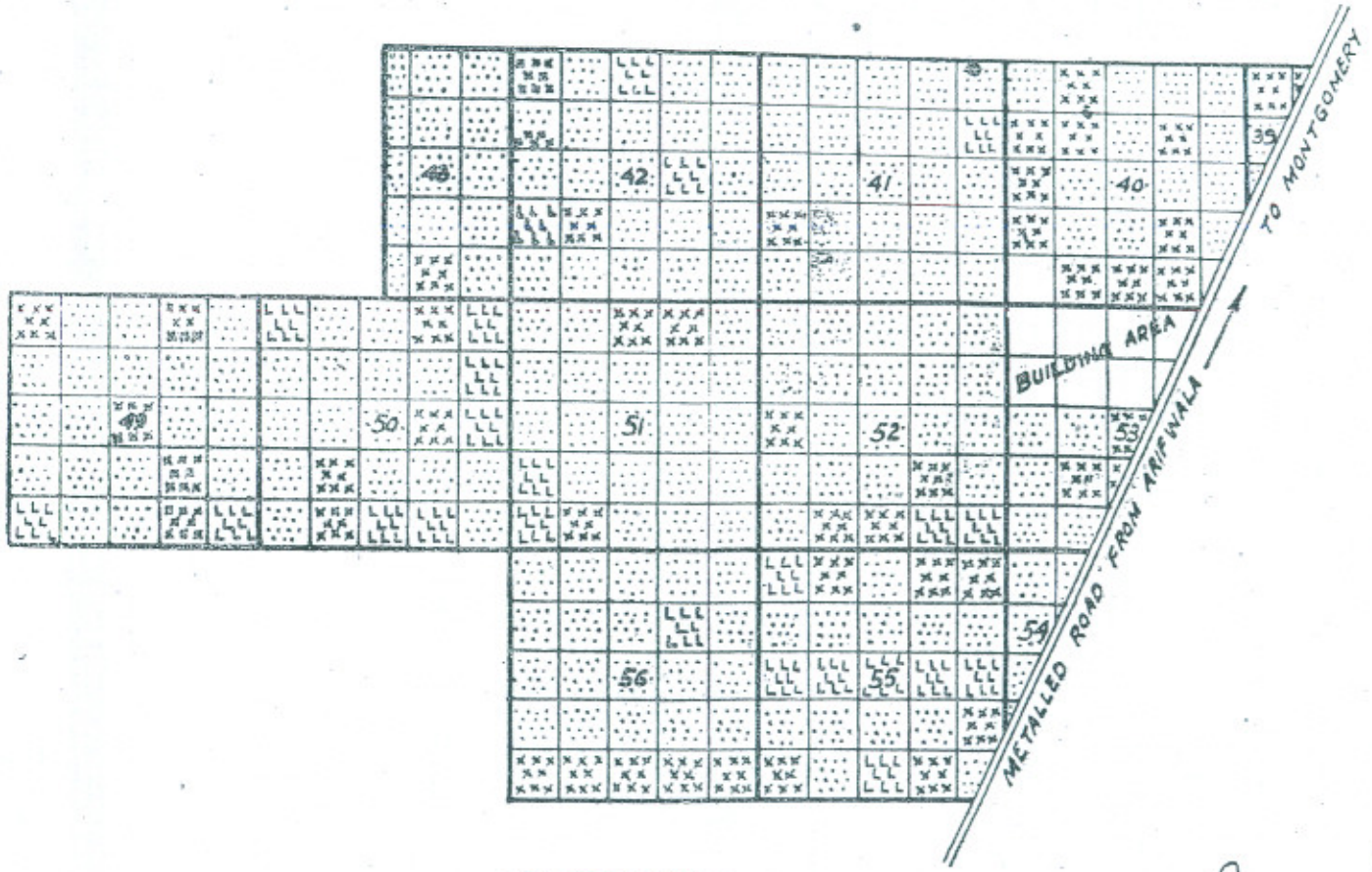
CANAL BANK MOGHALPURA LAHORE.

FIG. 2

BHALEWALA EXPERIMENTAL RECLAMATION STATION

PAPER No. 311

SHOWING DEPTH OF SOIL CRUST



—: REFERENCES :—

1. SOIL CRUST LESS THAN 6 FEET IN THICKNESS.---
2. SOIL CRUST 6 FEET TO 10 FEET IN THICKNESS.---
3. SOIL CRUST MORE THAN 10 FEET IN THICKNESS.---

Agoogloan

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