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THE SALT LANDS OF THE NIRA VALLEY.

BY

HAROLD H. MANN, D.Sc.,

Principal, Agricultural College, Poona.

AND

V. A. TAMHANE, L.A.G.,

Laboratory Assistant, Agricultural College, Poona.

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I. INTRODUCTION.

THE Nira Valley Irrigation Canal was opened in 1884. It passes through an area, formerly extremely dry and among the most famine-stricken in Western India, but possessing, as do so many areas in the Eastern part of the Deccan, an excellent deep black soil, which gave promise of first class returns if once water was supplied in abundance to the crops. Its construction was one of the first attempts to apply canal irrigation on a fairly large scale to a deep black cotton soil area. Before this, though irrigation wells are common in every part of the Deccan, and though the Mutha Canal already existed on the much shallower soil of an adjoining valley, no definite information existed as to the result which was likely to occur when the abundant supply of water from a canal was poured on to such land.

The immediate result was all that could have been expected. The Nira Valley became rapidly one of the richest tracts in the Deccan, but within about five years alarm was caused by the appearance of barren, salt-encrusted spots in some of the best and deepest lands in the Valley. Previously there was no record of the existence of salt land in the neighbourhood. In one or two villages there were brackish springs, and in a few places there are signs of salt in the banks of rivers, such as the Karha. But there were no large areas of salt land such as, for instance, existed in some of the Punjab Irrigation Colonies, before the introduction of the canal. But the salt land of which the first records occur in 1889 has nevertheless constantly increased in area since that date.

Naturally, from the beginning, the matter has caused great anxiety both to the people on the spot, and to the authorities responsible for the canal, and it has been frequently investigated in a more or less cursory manner. In 1893, for instance, Dr. Leather, Agricultural Chemist to the Government of India, went over the ground, took away a number of samples of the affected soils, and wrote a most interesting report printed early in 1894. At that time the barren land was increasing rapidly, and continued to do so for many years afterwards.

The matter ultimately became so serious that a Committee was appointed* in 1903 to consider what could be done. This was

* By Government Resolution No. 4044 of June 22nd, 1903, Rev. Dept. (Bombay).

composed of Messrs. Visvesvaraya, P. R. Mehta, and J. B. Knight, and their report issued* in 1905 represents by far the most careful consideration of the situation which has been made up to the present time. Their recommendations, as quoted in the Government Resolution dealing with the matter, were as follows :—

- “(1) The *nálás* should be opened out without delay in the neighbourhood of low-lying lands affected by water-logging or salt efflorescence. We recommend that a grant of Rs. 2,000 be made for dealing with the worst cases at first; with experience gained further measures may be devised and further funds allotted. . . . No doubt the damage is due to the introduction of the canal. . . .
- “(2) The affected survey numbers and the portions of them actually water-logged should be measured and sketches made and full remarks as to their condition recorded. The whole area of these four thousand and odd acres should be inspected and measured periodically, say, once in five years, to watch whether the evil is growing or diminishing, and, in either case, at what rate. These measures, while not being costly, will definitely locate the evil. With the aid of such a record it is easy to determine the magnitude and variation of the evil, and with the knowledge obtained it will be easy also to apply remedies.
- “(3) The Agricultural Department may be requested to have under observation the lands which are being improved by the cultivators. They may be inspected once a year to watch the effect of the remedies and to advise cultivators engaged in reclamation work. We noticed several commendable attempts at improvements; one instructive case was that of Survey Nos. 18 and 21 of Báramati. These and similar fields should be watched to see how far they improve under treatment now in progress. If Government see fit, the Agricultural Department may also be authorised to experiment with some of the remedies enumerated already and to prepare leaflets in the vernacular embodying in an easily intelligible form a description of the most successful methods of reclamation practised elsewhere.”

* As accompaniment to Government Resolution No. 8963, Rev. Dept., of 3rd November 1905 (Bombay).

The Government approved of the measurement of the survey numbers and the portions actually water-logged, and this was done once by the Survey Department in the early part of 1907. As it was done without expert assistance, the value of these measurements is not perhaps as great as might have been the case. We shall, however, refer to them later. With regard to the recommendation, that the Agricultural Department should keep under observation land which the cultivators are trying to improve, this has been carried out at intervals, and notes have been made by Mr. Knight and his staff, as well as by ourselves in the last year. Experiments were initiated under Mr. Knight's supervision in 1908, which have yielded some valuable results. During 1908 and especially 1909 we ourselves have visited the Valley frequently in connection with the matter.

II. EXTENT OF BARREN SALT LAND.

Before going on to discuss the results so far obtained, we must emphasise the seriousness of the matter. In accordance with the recommendations of the Committee of 1903, a careful survey of the lands affected by salt and water-logging was made by the Survey Department in 1907, with the result that an area of 4,870 acres was found to be damaged to such an extent that ordinary crops could not be grown. Now the total area supplied by the canal in 1907-08 was only 38,325 acres, and hence no less than 12.7 per cent. of this total area has been rendered more or less completely barren in the twenty-three years. This alone would make the question very serious one.

But this area would not perhaps have the importance which it really possesses, if it was not increasing. And hence the importance for our purpose of ascertaining how far it represents the ultimate damage which may be expected. In the early days of the canal there was no doubt about the matter. Year after year large pieces of land went out of cultivation, but the progress of the evil has not been so obvious in recent years. And yet we are convinced it is going on, and going on fairly rapidly for the following reasons.

In the first place, the universal testimony of the cultivators is that an increase in the salt area is taking place and in almost every village in which we have worked land has been pointed out to us which was quite recently under sugarcane cultivation but where this will no longer grow.

But more definite than this is the result of salt surveys made in 1904 and 1907. The former of these surveys was rough, and was made for the Committee of 1903: the latter was more accurate. Taken village by village, the results of these two surveys are as follows:—

Village.	Area actually damaged by water-logging and salt.		
	1904.	1907.	
	Acres.	Acres	Gunthas.
1. Bárámati	273	411	26
2. Medad	16	2	19
3. Malad Tarf Bárámati... ..	66	222	19
4. Gunawadi	206	393	36
5. Pimpli	174	113	31
6. Kanhari	165	42	5
7. Songaon	371	487	2
8. Nira Wagai	14	32	35
9. Sangwi	188	207	14
10. Khandaj	51	63	31
11. Korhale Khurd	21	10	28
12. Shirasne	28	78	27
13. Late	27	45	38
14. Pandhara	876	756	25
15. Kambleshwar	25	121	17
16. Karhale Budruk	260	260	17
17. Hol	505	492	38
18. Nimhut	172	omitted	
19. Murum	253	691	1
20. Karanje	324	400	3
21. Vadgaon ... ..	.....	34	35
	4,075	4,870	7

This would apparently indicate an increase of 835 acres of barren land in three years, or over 20 per cent. of the previously existing area. We are not inclined to lay too much stress on this exact figure, as the survey of 1904 was only a rough one, but it is significant that the damage appears to be getting worse in all the more seriously affected villages, with the exception of Pandhara and Hol.

There is a third very strong piece of evidence for the continuous increase of the evil in the condition of much of the land

which is still growing sugarcane of very high quantity. Sugarcane, as we shall have reason frequently to remark, is, when well manured and watered, a crop very resistant to damage by salt, and, as a rule, when it will not grow the land can be used for little else. Hence the interest of the following figures. They represent the analysis of the soil taken from first-class sugarcane land a few (generally eight to ten) days after heavy irrigation :—

	* Scrapings from surface Plot 1 (Málegaon Road), 8th May 1908.	* Scrapings from surface Plot 2 (Pandhara), 8th May 1908.	* Surface to 9" deep (Malad), 12th Feb. 1909.	* Surface to 9" deep (Malad), 12th Feb. 1909.
	Per cent.	Per cent.	Per cent.	Per cent.
Calcium Carbonate ...	'20	'06	'03	'04
Magnesium Carbonate ...	'11	...	...	...
Sodium Carbonate ...	...	...	...	'02
Calcium Sulphate ...	...	'40	'02	'01
Magnesium Sulphate ...	'03	'01	'02	'02
Sodium Sulphate ...	'72	'24	'01	...
Sodium Chloride ...	'21	'21	'15	'04
Total Salts ...	1'27	'92	'23	'13

Now all these results are very high. Ordinary black soil in the Deccan usually gives a percentage of soluble matters varying between '05 and '10 per cent. It is evident, therefore, that we have here evidence which indicates that under irrigation the salt increases in the soil, and that much of the land now under first class cultivation will inevitably pass out of cultivation, if the process at present going on is not arrested.

In summary, it may, we think, be said that the evidence is conclusive, that the area barren owing to salt in the Nira Valley is still increasing, and increasing fairly rapidly. This conclusion is based on the evidence of the cultivators, on the results of two surveys, and on analyses of the soils which are now bearing excellent crops of sugarcane. The evil is, therefore, likely to

* We are intentionally using a conventional method of combining the constituents found by analysis into salts in all the analyses reported in this paper, as we think that by this means their meaning can best be grasped. Potash is not usually estimated. Material alkaline to Potassium Hydrogen Sulphate using Phenol Phthalein as indicator is counted as Sodium Carbonate. All other carbonic acid is first combined with Lime, the excess with Magnesia, and again the excess with Sodium (as Bicarbonate). All Sulphuric acid is combined first with the excess of Lime, if any, then with the excess of Magnesia, if any, and then with Soda. All Hydrochloric acid is combined with the excess of bases in the same order. The total salts are obtained by evaporation, and gentle heating of the residue, in most cases, though in some only by addition of the figures for the various constituents.

become greater in the future, and it becomes important to ascertain the source of the salt, its precise effect on the vegetation and on the crops which can be grown, and the methods which can be adopted first for checking its spread, and then for bringing back the barren areas into cultivation.

III. SOURCE OF THE SALT.

We must first consider the source of the salt. Previous to the introduction of the canal the presence of salt incrustation was unknown. It has been suggested to us, however, that salt did occur in the district, and the name of one of the most important tributaries of the Nira River, the 'Karha,' has been cited as showing that salt was found, and had made this river salt long before the canal was opened. To make certain on this point we followed the course of the Karha River from Baramati to Jejuri in April 1909, when it was at its lowest, to see whether there was any evidence of salt deposits along its course or of brackishness in its waters.

The results obtained on this journey were striking. No salt was observed anywhere on the banks after the country watered by the canal was left, except in two or three places below villages or below land irrigated from wells. In these cases there was, in several cases, a white salty deposit some three or four feet below the surface on the river bank, composed chiefly of Sulphate of Sodium,—but this was all. The analysis of the water, at various points, gave the following results. I have incorporated the analyses taken at the same period in the previous year (1908). The first analysis represents the highest point on the river, and the samples proceed in order downward :—

	I at Jejuri.	II at Morgaon	III at Jalgaon Kadepa- thar.	IV at Nepat- walan.	V at Aque- duct near Baramati	VI below Baramati (1908).
	Parts per 100,000.					
Calcium Carbonate	6.0	9.0	12.0	13.0	2.0	22.0
Magnesium Carbonate	8.0	9.0	9.0	15.0	...	...
Sodium Carbonate	5.0	...	...	8.0	5.0	...
Sodium Bicarbonate	4.0	6.0	...	...	...	...
Calcium Sulphate	...	...	...	...	19.0	23.0
Magnesium Sulphate	...	...	6.0	11.0	18.0	66.0
Sodium Sulphate	4.0	7.0	18.0	48.0	91.0	150.0
Sodium Chloride	13.0	16.0	2.0	39.0	72.0	97.0
Total Salts	40.0	47.0	47.0	134.0	207.0	358.0

These results are clear. The first three samples are from the Karha river above the range of the canal influence. The analyses show this so-called salt river containing water which is exceedingly fresh for a Deccan water, constantly used for irrigation without any danger. So soon as one gets near the canal, and has the chance of seepage water through the soil, the salts begin to increase, until the river opposite Bâramati is exceedingly salt. In this case it is, therefore, evident that the salt is due to the seepage waters from the canal and not to any deposits of salt in the drainage area of the river.

We can, in fact, find no justification for supposing that (as does really occur in some parts of the Deccan, as for instance, in the Don river valley in Bijâpur or the Benihalla in Dhârwâr) obvious visible salt occurred anywhere in the district before the introduction of the canal, or that the river waters were even brackish.

Again, it can hardly be due to the canal water itself. The water of the Nira Canal is quite fresh, as the following analyses, taken in the dry time of the year, when the water is at its lowest, will show:—

	Pimpra, May 29th, 1908.	Bâramati, April 22nd, 1909.
	Parts per 100,000.	
Calcium Carbonate	8·0	1·0
Magnesium Carbonate ... ..	...	2·0
Sodium Carbonate	1·0	...
Sodium Bicarbonate ... ..	...	1·0
Calcium Sulphate	5·0	...
Magnesium Sulphate	4·0	...
Sodium Sulphate ... ..	...	3·0
Sodium Chloride	1·0	7·0
Potassium Chloride	5·0	...
Total Salts	24·0	14·0

This is evidently water which, if it properly drained through the land (or even if it does not), would take an indefinitely long time to produce any salt deposit. The canal water, as such, cannot be blamed for the extension of the area of salt land.

But if a hole is dug into the land at almost any part of the cultivated, flat, deep soil area under the canal, the water level is found to be from two to six feet below the surface, and the sub-soil water which runs into such a hole is invariably salt, whether the hole be dug in the first class cultivated land or in land which has become barren.

In the first place, let us take examples of sub-soil water obtained by digging holes in *good land* actually under irrigated sugarcane, and analysing the water which percolated into the hole. Typical examples are given from three villages:—

1. *Pandhara*.—All these fields were irrigated seven days previously.

Sub-soil water level.	I. 3 ft. 9 ins.	II. 3 ft. 4 ins.	III. 5 feet.	IV. 3 feet.
Parts per 100,000.				
Calcium Carbonate ...	20·7	4·0	4·0	18·0
Magnesium Carbonate ...	...	6·8	8·3	7·6
Sodium Carbonate ...	4·8	7·9	6·4	...
Sodium Bicarbonate ...	...	43·9	22·6	4·3
Calcium Sulphate ...	37·2	...	...	...
Magnesium Sulphate ...	29·0	...	...	...
Sodium Sulphate ...	...	18·9	8·2	11·2
Magnesium Chloride ...	18·6	...	...	...
Sodium Chloride ...	358·1	29·7	5·0	5·0
Total Salts ...	468·3	111·3	54·4	46·0

I.—The sub-soil in this case was medium black soil down to three feet deep, then white clay.

II.—The sub-soil in this case was medium black soil down to two feet six inches deep, then *murum* to three feet, then white clay.

III.—The sub-soil in this case was medium, black soil down to four feet, then red clay.

IV.—The sub-soil in this case was medium black soil down to two feet, then white sticky *murum* called '*Shenya murum*'.

2. *Málegaon Road (Bárámati).*—The land was irrigated seven days previously.

Depth of sub-soil water.	I. 4 feet	II. 4 ft. 6 ins.	III. 3 feet.	IV. 4 ft. 2 ins.
Parts per 100,000.				
Calcium Carbonate ...	36·9	9·0	7·0	23·1
Magnesium Carbonate ...	...	11·4	8·3	...
Sodium Carbonate ...	...	7·4	10·6	...
Sodium Bicarbonate ...	...	19·1	29·1	...
Calcium Sulphate ...	32·7	...	...	244·8
Magnesium Sulphate ...	32·4	...	...	258·5
Sodium Sulphate ...	68·9	46·3	8·5	85·4
Sodium Chloride ...	10·6	8·0	5·0	825·1
Total Salts ...	181·6	101·1	68·5	1,436·8

I, II, III.—The sub-soil in these cases was medium black soil down to the level of the sub-soil water.

IV.—The sub-soil in this case was medium black soil down to three feet six inches, then murum to four feet, and below this a sticky clay.

3. *Malad.*—The land has been irrigated in the first case given fifteen days previously, in the others nine days previously.

Sub-soil water level.	I. 6 feet.	II. 4 feet 6 ins.	III. 5 feet.
Parts per 100,000.			
Calcium Carbonate ...	23·1	8·0	29·2
Magnesium Carbonate ...	...	10·5	...
Sodium Carbonate ...	15·0	10·6	...
Sodium Bicarbonate ...	...	34·3	...
Calcium Sulphate ...	79·2	...	1 4·5
Magnesium Sulphate ...	31·4	...	70·3
Sodium Sulphate ...	47·0	40·8	133·0
Sodium Chloride ...	1·6	8·3	6·7
Total Salts ...	198·2	112·4	393·6

In each case the land was black soil down to the depth of the water.

It must be remembered that the land in each of these cases was producing first-class crops of sugarcane, and had only been irrigated with perfectly fresh water a few days before,—and yet the sub-soil water was decidedly salt in most cases. The samples might be classified thus:—

Very salt sub-soil water (over 150 parts per 100,000)	...	...	... 5 samples.
Moderately salt sub-soil water (between 100 and 150 parts per 100,000)	...	...	... 3 samples.
Slightly salt sub-soil water (between 50 and 100 parts per 100,000)	...	...	... 3 samples.

The amount of the salt seems to have no relationship to the character of the sub-soil, largely because, probably, the *murum* in these cases is very sticky, clayey, and impervious, often resembling white or red clay.

While these figures show a very general and frequent water level at five feet and under from the surface, of a decidedly salt character, even in the best land, the character of the water in the salt affected area is still worse, as the following tables will show. The figures are not, however, wholly comparable, because owing to the fact of the land from which the water was taken being affected with salt, it is not irrigated and hence the water will naturally be more salt than if fresh water were being poured over the land every ten days or so:—

1. *Mãlegaon Road*.—The land had not been in use for some years.

Sub-soil water level.	I. 2 ft. 3 ins.	II. 2 ft. 3 ins.	III. 2 ft. 9 ins.
Parts per 100,000.			
Calcium Carbonate ...	22·6	17·6	70·9
Magnesium Carbonate ...	...	...	...
Sodium Carbonate ...	1·2	...	1·2
Sodium Bicarbonate ...	...	...	...
Calcium Sulphate ...	130·5	169·0	185·8
Magnesium Sulphate ...	121·9	181·6	108·1
Sodium Sulphate ...	546·6	523·0	220·5
Sodium Chloride ...	40·4	37·9	158·8
Total Salts ...	863·2	929·2	745·3

In all these cases the sub-soil to the depth of the water was medium black soil.

2. *Malad*.—We have only one sample in this case. It was from a small patch where salt was developing in the middle of a field :—

Sub-soil water level.		I. 4 ft. 6 ins.
Parts per 100,000.		
Calcium Carbonate	... ..	16'0
Calcium Sulphate	... ..	543'0
Magnesium Sulphate	... ..	291'0
Sodium Sulphate	... ..	...
Sodium Chloride	... ..	1,622'0
Total Salts	... ..	2,472'0

These were, of course, from salt land itself, and hence contain much more salts than in most of the previous cases. All would be classed as very salt.

It is clear, therefore, from these figures that there exists, throughout a large part out of the Nira Canal area, sub-soil water of a salt character within five feet of the surface of the land,—and that this sub-soil water is found both in good first-class sugarcane land and salt affected land. This is a most important conclusion. It places the future of the Nira Canal area as much more doubtful than has hitherto been believed if the system in vogue in the past should go on. For with a generally salt sub-soil water, a slight error in treatment on the part of the cultivators will be very apt to bring the salt to the surface and ruin the land.

IV. COMPOSITION OF DRAINAGE WATERS.

It is to be noted, however, that the analyses which I have just given are of the sub-soil water actually existing in the land, as revealed by holes dug for the purpose, and are not analyses of the seepage waters which are found whenever an open drain is dug. The difference between the latter, and the sub-soil waters already given is very marked. The following table compares the water found in

a hole in the salt plots on the Málegaon Road with that in a drain flowing alongside (May 6th, 1908):—

	I.	II.
	Hole in salt land.	Drain flowing alongside.
	Parts per 100,000.	
Calcium Carbonate ...	22·6	17·0
Magnesium Carbonate ...	...	3·5
Sodium Carbonate ...	1·2	...
Calcium Sulphate ...	130·5	...
Magnesium Sulphate ...	121·9	11·1
Sodium Sulphate ...	546·6	71·5
Sodium Chloride ...	40·4	8·1
Total Salts ...	863·2	112·4

This is an illustration of what is found almost universally in the valley. Where there is a drain, which is running, alongside a place of salt land, it is always much less salt than the water actually in the land itself. When, however, the drain gets stopped or blocked for any reason, then it quickly becomes of the same composition. The meaning of this is plain. The water in the drains is, in fact, largely composed not of drainage water from the land, but of direct seepage water from the canal and distributaries, and from waste irrigated water taken in excess of requirements. If it were drainage from the land, it would have a composition not materially different from that of the water already in the land: if it is much less salt than the latter, it is evident that it is largely composed of fresh water which has never been in the land in the ordinary sense at all.

We are, in fact, driven to the conclusion that the general high level of the subsoil water under the canal in the Nira Valley is the cause of the larger part of the development of salt and barren lands, and that this high level is maintained by the continual seepage of fresh water which fills the drains and prevents the salt water draining out of the land naturally. It is necessary, in fact, to completely deal with the problem, first to stop the seepage and, second, to provide such adequate drainage as will allow not only such seepage as occurs to flow away but also reduce the subsoil water level very considerably. We recognise that to

do the first of these is, in more than a minor degree, beyond our power with the present canal. But the second is possible, and fortunately we are able to quote a case in which it has given a considerable success as a method of reclamation of slightly affected land.

V. RECLAMATION EXPERIMENTS AT PANDHARA.

In the report of Messrs. Visvesvaraya, Knight and Mehta of 1904 which I have already quoted, they recommend (para. 9-A of their report) that the natural drainage channels in one or two *nálás* should be deepened as an experimental measure and the effect noted,—and that the surrounding cultivators should be encouraged to make subsidiary drains to connect with such deepened *nálás*. This recommendation was carried out on two *nálás* in the Pandhara village in 1908, the areas drained by which contained very much land damaged with salt, and the result has been a very marked change in the character of these areas. The area of 1909 is based on a survey made by one of us. The effect is equally well indicated by the following figures :—

Total area affected before the work was undertaken on these two <i>nálás</i>	...44'59 acres.
Total area remaining affected in 1909	...34'07 "
Total area reclaimed	...10'52 "
Percentage reclaimed	...23 per cent.

When it is considered that Pandhara is one of the worst affected villages, and that the area draining into these *nálás* were chosen for their extremely bad character, the immense improvement is still more obvious. In 1910, a visit to the land indicated still further improvement. Much of the land absolutely barren two years previously was now beginning to cover itself with grass, and in one case sugarcane was again planted, though not very successfully, where no crop of any sort had been taken for nine years.

The means by which this change has been brought about are—

- (1) the opening of the *nálás* by means of a narrow deep drain three feet deep and three feet wide dug in the middle

of the bed. It was at first thought that a drain such as this, with sides as nearly vertical as possible, would not hold in black soil such as this, and more especially in soil containing salt. There was, in fact, continual trouble in the first year and the drains required constant watching. Since that time there has not been nearly the same need, though occasional cleaning out is still necessary. We look upon this form of *deep narrow* drain as essential to the method,—wide shallow drain (as was originally proposed in the present case) will not answer the purpose. The opening of these *nálás* or main drainage channels can only be done by the Government.

- (2) the digging of subsidiary drains from two to two-and-a-half feet deep to these *nálás* from the cultivators' field. To be most effective, these must be made of the same character as we have described—narrow, deep and banked up on the side,—so that no drainage water will enter the drain except *through* the soil and none over the surface. If surface wash into the drains be allowed, they will silt up exceedingly quickly, and the washing of the salt by rain and irrigation water out of the land into the drains will not take place. In the case in question these subsidiary drains have been made with the consent of and at the expense of the cultivators.

We see no reason why the wider application of the same method should not lead to similar results in other villages similarly affected. On one point, however, it is necessary to insist. The subsidiary drains will in many cases be of little use unless the main drainage channels (*nálás*) are deepened, and then kept open; as we have shown, the seepage water is now holding back the salt water in the land, and must have the chance to drain away before the latter can be got rid of. It is only a proportion of cases where the digging of small drains by the cultivators will be effective unless the larger work of opening the *nálás* and keeping them open be previously undertaken.

In the case at Pandhara under discussion, there has been a regular and constant stream of water in the deepened *nála* since it was opened. Its composition, here given, indicates that it principally consists of seepage water direct,—and it is quite fit to be picked up again and used for irrigation lower down.

Water from deepened nála.

February 12th, 1909.

	Parts per 100,000.	
Calcium Carbonate	...	12·0
Magnesium Carbonate	...	3·9
Sodium Carbonate	...	8·1
Calcium Sulphate
Magnesium Sulphate	...	4·3
Sodium Sulphate
Magnesium Chloride	...	6·5
Sodium Chloride	...	·7
		35·5
Total Salts	...	35·5

The nett result of the system of drains just described in the area covered by it has been—

- (1) the reclamation of land slightly affected ;
- (2) the reclamation of land affected by water-logging and not by salt ;
- (3) the improvement of lands moderately affected.

The time has not been sufficient to ascertain what the effect has been and will be on the worst cases, but everything would indicate that where the salt reaches beyond a certain seriousness, the effect of drainage such as we have described in recovering the land will be exceedingly small. It will *prevent the increase* of the salt, by lowering the water level, but the amount of drainage *through* the land in the Nira district, unless the land is kept constantly ploughed and carefully levelled, is so small that the effect of rain* in washing the soil is only slight. Where the land is slightly affected, the mere lowering of the salt subsoil water will probably be sufficient, and with a moderate amount of salt, salt-resisting plants will and do get a chance to grow, by growing they improve the drainage, and so allow water to drain *through* the

* The rainfall month by month for the past ten years at Bárámáti is given in Appendix A.

soil, and hence reclamation will go on slowly. But the evidence here is that in cases where the salt in the soil has become large, the mere withdrawal of the salt subsoil water will produce little effect on the land, unless it is levelled, bunded and ploughed. This levelling, bunding, and ploughing cannot pay unless more water than that supplied by rain is given to wash the soil.

We have insisted on this point because it is sometimes held that if irrigation water is withdrawn from salt affected land, the land will gradually recover. If the subsoil water is lowered by any means at the same time, then in the case of mere water-logging or a slight amount of salt, then the conclusion is probably, if not certainly, correct: if the land is moderately affected and the rain can be forced to pass through the land (whether by the gradual development of herbage or by frequent cultivation), then it *may* gradually become fertile again. In the case of bad attack, such as much of the area in Bārāmāti, Malad, and many other villages, the effect of mere withdrawal of irrigation water, even if accompanied by lowering of the subsoil water, will probably be practically nothing at all, and the land will remain barren for generations.

VI. NATURE OF THE SALTS IN THE SOIL.

We have so far discussed generally the condition of things in the valley, and also the methods by which the evil can be prevented from spreading and can be removed when it has not gone too far. It is now necessary to consider, more especially in connection with the possibility of reclaiming the more seriously affected areas, the nature of the salts found generally in such lands throughout the valley, the amount of them found in the soil, their relative effect on certain plants, and the ways which can be adopted to remove them.

The salts found in the soils are all derived, so far as one can tell, by the decay of the trap rock of which the basis of the valley is composed. Although these trap rocks are exceedingly resistant to ordinary weathering agents, they apparently yield very easily to water containing the salts usually found in this valley. The rocks, for instance, found in the bed of the Karha river near Bārāmāti are nearly all more or less rotten, and often so much so that they have lost entirely the hardness of the original rock. Such rocks as these in process of disintegration gave

on analysis the following figures. They were taken at the height of the dry weather :—

Disintegrating Rock in bed of Karha River.

6th May 1908.

	I.	II.
	Slightly disintegrated.	Much disintegrated.
	Per cent.	Per cent.
Total soluble salts	1·13	1·15
<i>Composition of Salts.</i>		
Calcium Carbonate	18·5	2·6
Magnesium Carbonate... ..	...	1·3
Calcium Sulphate	16·2	...
Magnesium Sulphate	12·3	1·3
Sodium Sulphate	28·5	12·5
Sodium Chloride	23·9	82·5

These analyses give a very fair example of what is found in the soils of the valley. There is very little Sodium Carbonate, very much Sodium Sulphate and Sodium Chloride, and always mixed with them is a varying quantity of Magnesium salts, chiefly Magnesium Sulphate, but often Magnesium Chloride also occurs. I give samples from several villages, both of incrustations from the surface, of scrapings of the dry powdery loose soil found on the ground where much salt occurs, and also of soil at a depth of three inches and nine inches.

I. *Bārāmāti (Mālegaon Road).*—Scrapings from the surface of barren land :—

	I.	II.	III.
	Per cent.	Per cent.	Per cent.
Total salts in dry soil ..	9·7	37·6	1·7
<i>Composition of Salts.</i>			
Calcium Carbonate ..	5·4	0·2	14·9
Magnesium Carbonate ..	...	...	7·9
Calcium Sulphate ...	3·4	0·4	...
Magnesium Sulphate ..	2·3	0·3	2·1
Sodium Sulphate ..	48·7	98·0	53·0
Sodium Chloride ...	40·0	1·2	15·1

II. *Bārāmāti (Mālegaon Road)*.—Samples of the top three inches of soil, and of that lying between a depth of 3 and 9 inches, from barren land (March 1909):—

	Sample I.		Sample II.		Sample III.	
	Surface to 3".	3"—9".	Surface to 3".	3"—9".	Surface to 3".	3"—9".
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Total salts in dry soil ...	3.0	1.5	3.2	2.8	2.2	2.1
<i>Composition of Salts.</i>						
Calcium Carbonate ...	3	4.4	1.3	1.4	.8	1.5
Sodium Carbonate ...	7	9	...	4	.8	...
Calcium Sulphate ...	11.2	2.3	19.6	20.8	31.6	28.9
Magnesium Sulphate ...	4.6	5.6	5.2	6.2	8.3	5.9
Sodium Sulphate ...	71.3	79.6	67.1	67.3	52.3	60.9
Sodium Chloride ...	11.8	7.5	6.9	4.0	6.1	2.9

III. *Malad*.—Samples of the top three inches of soil and of that lying between a depth of 3 and 9 inches (March 1909):—

	Sample I (Fertile spot).		Sample II (Barren high land).		Sample III (Spot with poor crop).	
	Surface to 3".	3"—9".	Surface to 3".	3"—9".	Surface to 3".	3"—9".
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Total salts in dry soil ...	3.9	2.2	3.86	1.06	1.58	.86
<i>Composition of Salts.</i>						
Calcium Carbonate ...	3.9	12.9	6.2	2.4	2.4	2.9
Magnesium Carbonate ...	...	5.9	...	...	...	...
Sodium Carbonate ...	4.4	8.6	2.6	1.1	1.6	7.0
Calcium Sulphate ...	20.3	...	28.0	12.5	37.3	8.2
Magnesium Sulphate ...	9.1	4.2	...	8.9	26.5	...
Sodium Sulphate ...	...	49.5	...	8.5	...	22.6
Calcium Chloride ...	...	...	16.2	...	...	...
Sodium Chloride ...	62.2	19.0	41.9	66.5	24.2	59.4
Magnesium Chloride ...	...	...	13.4	...	7.8	...

IV. *Pandhara*.—The soils represented in these samples are from two places. The first of these was a field which has borne no crop for eight years, and the second was from good sugarcane land almost adjoining, but from which the crop had been removed several months before, and which had no irrigation thereafter:—

	Soil I.			Soil II.		
	(1) Surface scrap- ings.	(2) Soil 1"—5" deep.	(3) Soil 5"—9" deep.	(1) Surface scrap- ings.	(2) Soil 1"—5" deep.	(3) Soil 5"—9" deep.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Total Salts in dry soil ...	2'35	1'78	3'58	'96	'52	'49
<i>Composition of Salt.</i>						
Calcium Carbonate ...	...	1'6	...	6'8	4'8	5'8
Magnesium Carbonate ...	...	1'4	...	...	...	6'0
Sodium Carbonate ...	'6	...	1'8	...	...	1'4*
Calcium Sulphate ...	28'0	...	1'9	43'0	3'2	...
Magnesium Sulphate ...	25'8	3'3	...	1'0	9'1	...
Sodium Sulphate ...	...	72'0	...	25'9	49'1	69'1
Calcium Chloride ...	...	...	'6	...	...	...
Magnesium Chloride ...	2'1	...	3'0	...	...	...
Sodium Chloride ...	43'4	21'8	92'7	23'3	33'8	17'8

* Bicarbonate.

These samples illustrate very well the variations which are found. In the samples from Baramati, for example, by far the predominating salts are Sulphates, and seeing that the amounts of Calcium and Magnesium is relatively small, they must be in by far the great proportion, in the form of Alkali Sulphates. In the samples from Malad, on the other hand, Chlorides are present in large quantity, and in some cases a considerable proportion is, it appears, present as Chloride of Calcium and Magnesium. The Pandhara samples lie between the other sets, but have the same general characteristics.

VII. EFFECT OF THE SALT ON VARIOUS PLANTS.

Land which is affected with these salts quickly becomes barren if dry. If the quantity of salt be small, then dwarf *babul* (*Acacia arabica*) trees establish themselves, and the common *tarwad* (*Cassia auriculata*) is also very frequent. The most

frequent plants, however, are grasses and sedges, the most frequent being *lowála* (*Cyperus rotundus*) and *kundá* (*Andropogon intermedius*) in the portions which are not water-logged. When these do not grow the land is absolutely barren, and during the reclamation of salt affected areas they are the first vegetation to appear. None of the plants found seem (except, perhaps, *kunda*), however, to be of much value for fodder or otherwise.

As none of the salt resisting plants actually found in the valley were of much value, it became of importance to ascertain what actual crops could best be used on land affected by salt during reclamation. Of all those commonly grown, sugarcane seems least injured, provided that a sufficient amount of irrigation water and organic manures be used. This last point is important because the prevalence of salt in land actually under sugarcane would seem to furnish the reason, at the same time for the immense quantities of manure which are put on for this crop, and which exceed, I think, the amount used in any sugarcane region in the world, and also for the large amount of water,—very excessive according to all standards,—which is commonly used.

With regard to the former point, I have made very careful enquiries of the cultivators as to the amount of manure which is actually put on by them in former days and now. The testimony is almost universal that there has been a very great increase. In the neighbourhood of Bárahati, the custom eight or ten years ago was to put on about 1,500 cubic feet of cattle manure, and five to seven *khandis* of oilcake per acre: at present the quantity is 2,500 cubic feet of cattle manure and eight to ten *khandis* of oilcake on the same area. Putting these *data* into pounds we have as follows:—

(1) *Formerly*—

Cattle manure	... about 45,000 lbs.
Oil-cake	... about 3,000 „

(2) *At present*—

Cattle manure	... about 75,000 lbs.
Oil-cake	... about 4,500 „

With this manuring, the yields are very high, but the testimony is somewhat conflicting as to whether the amount of *gul* obtained per acre has generally increased. Most of the substantial growers of cane maintain that the yield they expect has not materially changed, and that formerly, as now, they expected to

obtain 500 maunds of 25 pounds per acre or about 12,500 pounds of *gul*: others state that there has been some increase in the yield. On the whole we are inclined to think that the crop of sugarcane has become somewhat heavier, but it has not increased to anything like the extent that the amount of manure has. The actual amount of manure now used may be best realised, perhaps, when the amount of Nitrogen it represents is given, and which is put on to the land each year. The oil-cake generally used and preferred is castor cake, or more recently safflower cake. The former of these as prepared in Western India contains about $4\frac{1}{2}$ per cent. of Nitrogen,* and the latter 6 to 7 per cent. The cattle manure is prepared without much litter, is dry, and contains from .8 to 1.0 per cent. of Nitrogen. We, therefore, have as the present dressing—

(1) *Using castor cake—*

Cattle manure	...	75,000 lbs.	=	675.0 lbs.
Castor cake	...	4,500 „	=	202.5 „
				Total = 877.5 lbs.

(2) *Using safflower cake—*

Cattle manure	...	75,000 lbs.	=	675.0 lbs.
Safflower cake	...	4,500 „	=	270.0 „
				Total = 945.0 lbs.

This amount is, of course, enormous. Not only does it far exceed the quantity used, we think, anywhere else in the world, but it far exceeds the amount which, it is found, can be profitably applied at the Mánjri Sugarcane Station belonging to the Department of Agriculture, Bombay. There the standard dressing is 350 pounds of Nitrogen per acre, but the cultivators

* Analyses of typical samples of safflower cake and of castor cake as commonly used are as follows:—

		Safflower cake.	Castor cake.
		Per cent.	Per cent.
Nitrogen	...	6.42	4.76
Phosphoric Acid	...	1.72	1.21
Potash	...	1.78	1.77

in the Nira Valley maintain that this amount is absolutely insufficient under their conditions. The only reason we can suggest for this is the constant presence of salt in the soils of the Nira Valley. The following analyses, all taken from land where a *first class* crop of sugarcane was growing or had grown, indicate the widespread salty character of the soil :—

Sample I.—Soil from Malad. Sample represents a section from the surface to 9 inches deep, ten days after a heavy irrigation.

Sample II.—Soil from another plot at Malad, under similar conditions to sample I.

Samples III, IV and V.—Scrapings from the surface: soil from one inch to five inches deep: and soil five inches to nine inches deep respectively from a field which had borne an excellent crop of sugarcane removed two months previously.

	I.	II.	III.	IV.	V.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Total salts in dry soil	·28	·17	·96	·52	·49
<i>Composition of Salts.</i>					
Calcium Carbonate	13·7	30·8	6·8	4·8	5·8
Magnesium Carbonate ... ..	...	...	...	...	6·0
Sodium Carbonate ... ..	...	15·0	...	...	1·4*
Calcium Sulphate	7·3	5·3	43·0	3·2	...
Magnesium Sulphate	10·7	13·5	1·0	9·1	...
Sodium Sulphate	3·0	...	25·9	49·1	69·1
Magnesium Chloride ... ..	...	3·0	...	...	...
Sodium Chloride	66·2	32·3	23·3	33·8	17·8

* Bicarbonate.

When one considers that the soils represented by samples I and II were under constant irrigation every ten days at the time, and that the bulk of the salt would undoubtedly be in the subsoil, these analyses indicate that the actual good first-class sugarcane land is already affected with salt.

Now it is very well known that one of the methods of treatment most commonly recommended in land slightly affected with

salt is the application of large quantities of bulky organic manure. It seems that the cultivators have found this out empirically, and as the salt tends to increase in the soil, they have constantly increased the amount of manure applied, in order to neutralise its effect,—ultimately reaching the enormous applications already detailed.

This matter is a very important one in connection with the question of manure supply. Sugarcane growing is very profitable, and hence manure can be drawn from very great distances. Cattle manure, for instance, is brought to Baramati in bags containing from 100 to 130 pounds of manure, and there sold at the rate of 4 annas per bag for sugarcane. This depletes other areas, to an extent which would be quite unnecessary if the salt was absent, for then (as at Manjri) the manure could be reduced to less than half the present amount with practically the same result.

But the presence of salt also leads to the use of excessive quantities of water,—the object being to keep the salt in the subsoil. This may be and, in our opinion, probably is one of the causes for the demand for so much water on the part of sugarcane cultivators,—an amount which, as has been shown at Manjri, is far in excess of what is required for the successful cultivation of the crop. The use of large quantities of water has often been recommended as a means of checking the evil effect of slight saltiness in land. We only suggest the probability of a connection between the excessive demand for water and the salt undoubtedly present in the good sugarcane land: we have made no experiment to prove it.

Leguminous Crops.—It seemed a matter of importance to determine the behaviour of a number of other crops commonly cultivated in Western India, in order to find out the most suitable to use during the reclamation of land. Those, of which an account follows, were set out and arranged by Professor J. B. Knight, to whose courtesy I am indebted for permission to use his results. Of special importance in this connection were leguminous crops, as these may have considerable value in reclamation work.

Five plots were, therefore, set out in the *rabi* season of 1908, with *Gram* (*Cicer arietinum*), *Wal* (*Dolichos lablab*), *Chowli* (*Vigna catiangu*), *Udid* (*Phaseolus radiatus*) and *Lakh* (*Lathyrus sativus*) on a plot fairly seriously affected with salt (principally sulphates) in Baramati. Previous to their planting, this land had

carried salt rice, and was drained with deep open drains on all four sides. The direction of natural drainage was from North to South. The amount of salt in the soil of the plot was remarkably even, as is shown by the following analyses made almost at the conclusion of the experiment (February 1909).

The samples of soil were from the surface to 4 inches deep : the sub-soil represented a section from 4 inches to 9 inches deep in each case.

	Udid strip.		Chowli strip.		Wál strip.		Gram strip.	
	Soil.	Soil.	Subsoil.	Soil.	Subsoil.	Soil.	Subsoil.	
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	
Total salts in dry soil ...	0·476	0·446	0·206	0·420	0·998	0·420	0·332	
<i>Composition of Salts.</i>								
Calcium Carbonate ...	7·14	5·83	12·62	4·76	0·50	5·24	6·63	
Sodium Carbonate ...	1·05	1·12	0·97	5·00	1·41	1·19	1·51	
Calcium Sulphate ...	11·56	36·55	33·00	3·33	3·42	30·70	14·45	
Magnesium Sulphate ...	11·14	27·80	28·65	9·53	3·52	15·24	1·21	
Sodium Sulphate ...	65·96	21·52	8·74	57·86	10·05	20·49	49·09	
Sodium Chloride ...	3·15	7·18	16·02	19·52	81·10	27·14	27·11	
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	

The evenness of the total salts in the plots is very remarkable, though their character differs. The growth of the plants was, however, very different. The following were the results :—

Lákh (*Lathyrus sativus*) germinated well, but was rapidly injured, and, as a crop, uniformly failed.

Udid (*Phaseolus radiatus*) also germinated well, but rapidly became unsatisfactory over the greater part of the plot. The roots only penetrated to a depth of four inches, and no nodules were found on them whatever.

Chowli (*Vigna catiáng*).—This crop was much better than *Udid* and *Lákh*, and gave a very fair yield throughout. The actual amount worked out at 800 lbs. of grain per acre. The plants were practically all healthy and the roots penetrated usually to a depth of nine inches with a limited number of root nodules. In one case the roots were found to go to a depth of fourteen inches.

The effect of small bunds between these plots, which were put in across the line of drainage, was very marked in this case. The plants immediately above this bund were the worst in the plot: those below were the best. Analyses were made of samples of soil from the two places, as follows. The terms 'soil' and 'subsoil' have the same meaning as in the last table:—

	Below the bund.		Above the bund.	
	Soil.	Subsoil.	Soil.	Subsoil.
Total salts in the soil ...	0·166	0·176	0·446	0·206
<i>Composition of Salts.</i>				
Calcium Carbonate ...	9·64	14·77	5·83	12·62
Magnesium Carbonate...	5·42	...	...	...
Sodium Carbonate ...	3·61	2·84	1·12	0·97
Calcium Sulphate ...	...	63·65	36·55	33·00
Magnesium Sulphate ...	9·04	2·84	27·80	28·65
Sodium Sulphate ...	57·83	...	21·52	8·74
Magnesium Chloride ...	...	11·35	...	...
Sodium Chloride ...	14·46	4·55	7·18	16·02
	100·00	100·00	100·00	100·00

These figures and the appearance of the plot show the great part surface drainage takes in the movement of salt, for the samples were taken within three feet of one another. The higher figures given above represent the limit of tolerance of the salt, as the plants there were somewhat damaged.

Wál (Dolichos lablab).—In appearance this was the best crop of all those which were grown. A few plants only were slightly damaged, and the soil of which the analysis was given on a preceding page was near such plant, and, hence, represents the limit of tolerance of the crop. The actual yield per acre worked out at 740 pounds of grain. Very few root nodules were found. The roots penetrated to a depth of ten inches.

Gram, though germinated successfully, gave a poor crop, more especially in patches. No nodules were found on any of the roots, even on the large good plants: few, if any, roots went deeper than six inches. The crop was so small that its weight was not recorded.

Taken generally, we may say that among the common leguminous crops of the country, *Wál* and *Chowli* are considerably the most resistant, and should be used during reclamation experiments, at any rate when Chlorides and Sulphates form the chief part of the salt. Of these they will stand an amount which reaches .4 per cent. in the dry soil, near the surface, in the hot weather. Next to these, but much inferior for the present purpose, come *Gram* and *Udid*, while *Lákh* was a complete failure.

The only other crop with which experiments were made extensively by Professor Knight was rice, obtained specially from the salt land near the coast in the Konkan. Of course, its growth involves very frequent irrigation, and this involves careful drainage, but it may be said generally that sown '*rata*' rice did not do so well as '*Manjarwel*' rice transplanted from a good seedbed. On the plots above described afterwards devoted to leguminous crops the rice did well, and was counted as from 80 per cent. of a full crop to a full crop over most of the area. The remainder of the area was much inferior, but I have no data as to the amount of salt there present before or after the rice was grown.

Many small plots were laid out in 1909 by Professor Knight to ascertain the most resistant of the country crops. His results pointed to *Ambádi* (*Hibiscus cannabinus*) as the most resistant plant to Chlorides and Sulphates, in common cultivation. The amount which it will stand was not, however, determined.

On the whole, I think it may be taken that we know no crop that will grow successfully on land seriously affected with salt in the Nira Valley. Some are useful during reclamation, notably some of the salt rices from near the coast. Some leguminous crops will grow in land which contains a certain amount of salt, the best of them being *Wál* and *Chowli*. Beyond these, sugarcane will stand as much salt as most crops. But any attempt to use any of these crops for directly reclaiming the land must be dismissed. They may be useful by rendering if possible to use the land during reclamation, but this is all,—the reclamation must be independent of them.

VIII. SUCCESSFUL METHODS OF RECLAMATION.

The method which has proved successful in the worst cases is, as would have been expected, a combination of heavy watering and drainage. It seemed doubtful when these experiments were initiated how far black cotton soil severely attacked by salt would

be capable of being drained. Under these conditions it forms a black mass, which only drains very slowly, which behaves as a sticky slime, and which loses its faculty of cracking on drying. This being the case it was stated at the commencement (1) that open drains would never remain open in these areas and (2) that even if they did remain open the water would never drain into them.

It was, therefore, necessary to ascertain how drains which would remain open could be dug, and whether a cheap but effective close drain could be devised. After these questions were settled, the best method of arranging the drains for the purpose of getting as much salt as possible out of the land remained to be ascertained.

In the first place, the most effective form, or rather the only effective form, of open drain which would not silt up almost at once, was found to be a narrow trench two and-a-half feet deep, six inches wide at the bottom and about two feet wide at the top,—in which the material taken out of the drain was thrown at least two feet away from the drain so as to form a bund on both sides. It was found to be essential that *no surface water should run into the drain*, and hence the bund must be complete on both sides, and, further, it was necessary that the contents should be thrown far enough away from the drain so as not to simply run into it again when on wetting it took on the treacle-like consistency characteristic of this land when salt. If a drain like this was made, it would remain open, with only a little falling in of the sides, during the first year. A deeper drain could be made successfully in a similar way, but more difficulty was experienced in keeping it open. Such drains were effective in very bad cases of salt such as occurs in the Nira Valley.

Such drains have only a limited application as it is evidently necessary to have drains much more close together than it is possible to make such open drains. A series of drains on different systems were, therefore, laid out by Mr. Knight, in order to ascertain the relative amount of drainage from each. He has kindly permitted me to use his results. The drains were five in number, and were laid out two and-a-half feet deep in salt land :—

No. I was open, and constructed as above laid down.

No. II was dug, and filled to within six inches of the surface with *bábul* branches and twigs, and then filled with soil.

No. III was dug as before, and filled with sand to a depth of six inches, and then again filled up with soil. It required six cart-loads of sand per 100 running feet.

No. IV was dug as before, and tiles six inches in diameter placed in it.

No. V was dug as before, but partially filled with broken tiles.

Each drain was one hundred feet long and each depended solely on natural rainfall. No surface drainage could enter the open drain. The cost of each of these per 100 running feet was as follows:—

No. I	... Re. 1.
No. II	... Rs. 2-8.
No. III	... Rs. 2-12.
No. IV	... Rs. 15-4.
No. V	... Rs. 19-6.

The high cost of the tiles was on account of their not being usually made locally, and does not in any way represent what would be the regular cost.

The amount of water which drained from each drain from August 10th to August 31st, 1909, during which time 2.32 inches of rain fell, was as follows:—

No. I	... 1,845 gallons.
No. II	... 1,602 „
No. III	... 846 „
No. IV	... 3,918 „
No. V	... 2,109 „

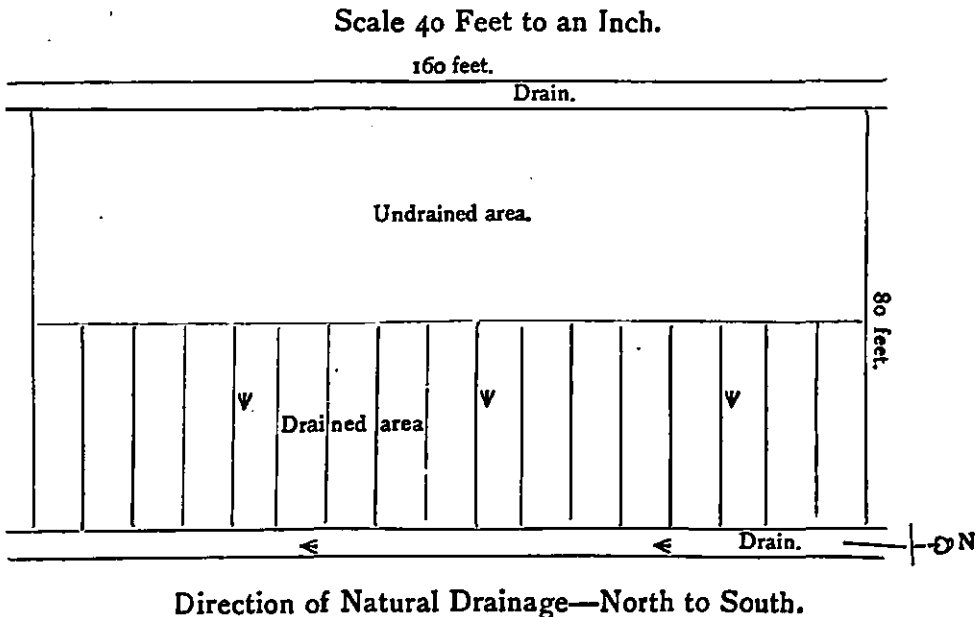
This result places, out of count, as practicable methods Nos. III, IV and V, owing to inefficiency or cost. An additional objection to No. IV (the tile drain) is that with the extreme contraction and expansion which takes place in a black cotton soil, the tiles rapidly get separated from one another, and cease to form a drain.

We are practically limited to open drains, and to drains formed of *bábul* branches or some such local material to be had cheaply and easily gathered in the immediate neighbourhood.

This being the case we proceeded to test the efficiency of a series of *bábul* drains on a piece of land very badly affected and encrusted with salt.

In this case, drains were put in across the general line of drainage of the land, two feet six inches deep, and filled with *bábul* branches as described, at a distance apart of ten feet only, the object being to determine the possibility of draining the land rapidly. The land was previously heavily encrusted with salt, and the water level in the driest weather was only two feet below the surface, although two drains existed only eighty feet apart and three feet deep *running in the direction of the natural drainage* on each side of the block. The land taken lay between these drains: the drains now put in (across the natural drainage) extended for half the distance (forty feet) between the deeper drains. The following sketch indicates the arrangement :—

Fig. 1.—Plan of Drainage Experiment.



The *bábul* drains began running almost immediately with very salt water, and with the advent of the monsoon, salt rice was planted with frequent, almost daily, irrigation. The drains worked exceedingly well from the beginning running almost constantly, and (where no crop of rice whatever had grown the previous year, even with heavy irrigation) the crop grew vigorously from the beginning. The water running from these drains smelt very

strongly of sulphuretted hydrogen, and a white deposit of sulphur was formed at the mouth of each of the drains. This shows how strong the reducing actions were in this soil and how these alone, apart from the salt itself, by producing ferrous salts and sulphuretted hydrogen, are destructive to plant life.

But the most important point was most visible six months later in the height again of the hot weather. The character of the soil was quite changed, where the *bábul* drains were, and no further. The remaining half of the block to which these *bábul* drains did not extend was encrusted with salt, and in a hopeless physical condition nearly as bad as before. The portion where the drains were, on the other hand, was in excellent condition, and, we believe, would grow sugarcane without difficulty, judging by experience in other cases. This would seem to prove—

- (1) that drains running *in the direction* of the natural drainage of the land, under the special conditions of the salt land of the Nira Valley are of little use for actual drainage out of the salt. Their action is, at least, very slow indeed ;
- (2) that drains running *across the direction* of the natural drainage, are immediately effective, and combined with copious irrigation will clear the worst land in a year. Their effect, however, only extends through their length, and practically no further ;
- (3) that drains made by half filling trenches two and-a-half feet deep with *bábul* branches and twigs are quite effective in the black cotton soil of the Nira Valley.

The drains used in this experiment were, we fear, impractically near to one another, in some cases at any rate, as the cost would be very great. The next and remaining question to solve, is as to what distance such drains may be apart in order to get a similar effect. In this case the cost of the drains was as follows :—

Digging and filling the trench	
per 100 running feet	... Rs. 3-8-0
Collecting <i>bábul</i> branches per	
100 running feet	... <u>Rs. 2-8-0</u>
Total	...Rs. 6-0-0

The cost works out at about Rs. 250 per acre, which at first sight appears extremely excessive, and in many cases is really so. But it must be remembered that here the whole of the labour both for digging and for collecting the *bábul* branches had to be paid for, whereas usually a cultivator would do it himself during the slack months of the year. The cost will vary much too, and Mr. Knight succeeded, within two miles of the area we have been discussing, in getting similar drains made and filled at a cost of Rs. 2-8-0 per hundred running feet* or, putting drains at the same distance apart, about Rs. 110 per acre. When it is considered that it is not unusual for a cultivator in these rich tracts to actually cart and cover such salt land with fresh earth at an enormously greater cost, to get a few years respite from salt incrustation, the cost will not appear too excessive in all cases.

We have thus got a method, which, in the course of a single year, will apparently convert land without any market value into land worth at least Rs. 500 per acre, in the black soil of the Nira Valley.

Two questions remain with regard to the above :—

- (1) How near must the drains be to produce this effect ?
- (2) How long such drains continue to be effective ?

We are not, at present, in a position to give a definite answer to these questions. They can only be settled by continued experiment in the field. But in connection with the second there is one point which should be noted, namely, that if once the excess of salt is removed from the land it is not likely to accumulate again, if the subsoil water is kept a sufficient distance below the surface,—and that hence even if such drains do become ineffective after three or four years they will have done their work, and are not likely to be again needed provided the regular drainage of the land is attended to as described in the first part of this paper.

IX. CONCLUSIONS.

We may now summarise the positions which, we think, have been established in the present paper, and which, we venture to suggest, show a clear way out of the condition of things which prevail in connection with the development of salt land in the Nira Valley.

* *Vide* page 28 .

1. The development of salt land in the Nira Canal area is due solely to the existence of the canal, and to the raising of the water level in the country by the canal. The same phenomenon will always be liable to occur when a canal is placed in a district with deep black soil, where provision is not made to prevent the undue rise of the ground water level, in other words, for drainage.

2. The area of barren salt land is rapidly increasing, probably by about six or seven per cent. per annum.

3. Its extension can be prevented, and lands only slightly affected by salt can be reclaimed (as proved at Pandhara) by the deepening of the main drainage channels—chiefly *nálās*,—by the Government, and the provision of feeder drains from the areas under irrigation and below them, as described previously.

4. Apart from the areas actually become barren, almost the whole of the land now under canal irrigation is more or less salt, but not yet sufficiently so to injure the crops. The presence of this salt probably in part accounts for the abnormal and excessive amounts of manure used for sugarcane, and for the demand for excessive quantities of water,—and so leads to enormous and unnecessary waste of both water and manure.

5. The restriction of water will, so far as it tends to lower the level of the subsoil water, in so far prevent the extension of barren land, and may lead to the reclamation of some of the land now slightly salt. It will not, however, be a means of reclaiming the cases where the salt has become serious.

6. It has been said that the mere withdrawal of water from land will lead to its gradual recovery. This may be the case where the salt is very slight, but there is no evidence that serious salt land can be so recovered and made available for crops in any reasonable period, if ever, in the dry climate of the Nira Valley.

So far these conclusions deal with the prevention of the extension of salt areas, and the recovery of those only slightly affected. With regard to those already seriously barren, we may say as follows :—

- (1) the only method successful hitherto has been the digging of drains at least two and-a-half feet deep, across the line of natural drainage of the land, with an adequate outlet, and then after banking up the land, washing the salt through by frequent irrigation.

- (2) If this be done round areas of one-quarter to half an acre, the land gradually improves.
- (3) If frequent small drains two and-a-half feet deep (across the natural drainage) half filled with *bábul* branches or their equivalent be dug across a plot, with adequate outfall, and liberal irrigation given, very badly affected land can be recovered *in one year* so as probably to be fit to grow ordinary crops, especially sugarcane. The least distance apart necessary with such drains has not yet been determined. Tile drains are unsuitable in black soil.
- (4) Only drains are effective which run *across* the natural drainage channels.
- (5) No open drain is any use into which there is drainage from the surface.
- (6) Even in black salt-affected soil, open drains can be kept open with little difficulty, provided they have regular attention if (a) the sides slope from two feet wide at the top to six inches wide at two and-a-half feet deep, (b) the material taken out be thrown at least one to two feet away from the drain so as to form a continuous *bund*.
- (7) Salt rice from the Konkan can be grown during the process of reclamation, after the worst part of the salt is removed,--and during the first year if *bábul* drains are put in. The most resistant leguminous crops are *Wál* (*Dolichos lablab*) and *Chowli* (*Vigna catiáng*). *Ambádi* (*Hibiscus cannabinus*) is very resistant to salt.

These results make clear, as we have already said, the methods necessary for the prevention of further extension of salt development, and the reclamation of salt-affected land, and one or two questions only remain. It is not yet quite clear how much money it will pay to expend. But when one considers that the land is valueless and unsaleable at present, that once recovered it is worth at least Rs. 500 per acre in the case of good land, that the salt-affected areas are naturally the best, and that once recovered, with care there is no reason why the salt should reappear, it will be seen that a large cost per acre is not out of the question.

During the carrying out of this work, we have had the continuous help of Professor J. B. Knight, and his staff,—in fact, he has freely placed in our hands the results of his own experiments for use,—and for this we owe to him our best thanks. The Irrigation authorities have also co-operated on all occasions, and to them (particularly to Mr. V. N. Vartak, Executive Engineer for Irrigation for Poona, and to Mr. H. C. Crossle, the Engineer in charge of the Canal) we venture to express our sincere acknowledgments.

APPENDIX A.

Rainfall at Baramati, 1901—1909.

		1901.	1902.	1903.	1904.	1905.	1906.	1907.	1908.	1909.
		Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
January	...	1'77	0'90	...	...	...	2'19	..	...	...
February	...	...	...	...	...	0'15	...	0'18	...	...
March	...	0'45	...	...	...	...	...	0'15	0'39	...
April	...	1'54	...	...	...	0'03	...	3'15	0'04	...
May	...	0'32	0'40	2'22	0'40	1'34	0'38	...	...	...
June	...	3'29	2'67	3'56	1'56	2'89	4'86	4'39	2'88	...
July	...	1'33	1'05	3'31	0'45	1'26	1'09	2'46	1'50	...
August	...	2'24	0'66	1'35	0'07	1'95	9'49	1'45	1'46	...
September	...	5'54	5'75	7'09	5'87	0'29	5'05	5'24	8'89	...
October	...	0'65	3'91	1'79	3'83	4'12	1'02	...	1'37	...
November	...	0'24	0'89	...	...	0'41	0'49	...	...	...
December	...	...	3'15	...	...	...	0'13	...	...	...
Total	...	17'37	19'38	19'32	12'18	12'44	24'70	17'02	16'53	...