

Department of Agriculture, Bombay

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SOILS OF THE BOMBAY PRESIDENCY

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SOILS OF THE BOMBAY PRESIDENCY

CHAPTER I.

INTRODUCTION.

The importance of soil study in connection with agriculture has been long recognised. In recent years this study has received a great impetus on account of the establishment of the International Commission of Soil Science. They are going thoroughly into the various methods and processes used in soil study by different laboratories and are modifying them in such a way that they may be uniformly used by soil students all over. In the Bombay Presidency no soil survey has been done so far, but since the establishment of the Chemical Laboratory of the Agricultural Department a very large number of soil samples have been analysed. These, however, were not necessarily fully analysed. They were generally analysed according to requirements: some for chemical constituents, others for the mechanical separates, and still others for the soluble salts only and so on.

The analytical figures of various soils in the Presidency have accumulated in large numbers and they supply very valuable information about the soils. It is, therefore, proposed to publish them in a suitable form.

Historical.

The analytical figures of the soils from the various Government farms and the Government agricultural schools are in many cases published in the reports of these institutions. Besides these, however, there are other publications which deal with the soils of the Bombay Presidency in some form or another and these are given below:—

The Bombay Agricultural Department Bulletin No. 39 of 1910 on "The Salt Lands of the Nira Valley" by H. H. Mann and V. A. Tamhane gives soluble salts from salt affected soils derived from the Deccan trap in the Nira valley.

Bulletin No. 64 of 1914 on "Alkali or Kalar Experiments and Completion Report of the Daulatapur Reclamation Station, Sind", by G. S. Henderson gives the quantities of the various soluble salts in the Kalar lands of Mirpurkhas and Daulatapur.

Bulletin No. 83 of 1917 on "The Spice Gardens of Sirsi in Kanara" by D. L. Sahasrabudde gives detailed analyses of a large number of soils from North Kanara District. It contains figures for the chemical and mechanical constituents, soluble salts and also available potash and phosphoric acid from those soils.

Bulletin No. 96 of 1920 on "Investigations into the nature of the salt lands in Sind" by V. A. Tamhane gives soluble salts of the Kalar lands in Sind and also mechanical and chemical constituents of some of the Sind soils.

Pusa Memoir (Chemical Series) Vol. VIII No. 5, November 1925 on "Nitrogen Recuperation in the soils of the Bombay Deccan" by D. L. Sahasrabudde and J. A. Daji, gives the chemical analysis of the Deccan medium black soils and the changes in its nitrogen contents under varying conditions of temperature and moisture.

Bombay Bulletin No. 155 of 1928 on "The Die-back Disease of Citrus Trees and its relation to the soil of Western India" by G. S. Cheema and S. S. Bhat discusses suitability or otherwise of certain soils in the Deccan for citrus plants.

Bombay Bulletin No. 157 of 1929 "A study of the Soils associated with the deterioration of the Cardamom Crop in North Kanara" by D. L. Sahasrabudde and G. M. Bapat gives details of the ammonifying and nitrifying powers of the garden soils near about Sirsi, when kept under varying conditions.

Besides these there are two publications of the Public Works Department by C. E. Inglis and V. K. Gokhale. In their Technical paper No. 13 of 1926 on "Soil and Sub-soil Surveys in the Deccan Canal areas" an attempt is made to explain how to recognise soil and sub-soil conditions for irrigation purposes by observing vegetation and the different strata as found by taking bores up to eight or ten feet. Their second paper (Public Works Department Technical Paper No. 24 of 1928) deals with the construction of drains and other attempts to improve the salt lands.

Interpretation of Analytical Figures.

Methods of analysis are given in the appendix. The analytical figures are valueless if we are not able to understand their exact meaning. It is, therefore, essential that we must give a general idea as to what meaning we put on these figures in the light of our experience and it is with this object that the interpretations of the results are given below.

Interpretation of results.—The most important of the chemical determinations are loss on ignition, lime, potash, phosphoric acid and nitrogen.

Total constituents.—The proportion of the loss on ignition indicates the amount of organic matter and water held by the soil, which is not driven out at 100°C. It should ordinarily be not less than 4 per cent.

The usual standards for nitrogen and phosphoric acid may not hold good in the case of Indian soils. According to Voelcker and others, Indian soils, in general, are poor in nitrogen and phosphoric acid. The nitrogen in good Indian soils is considerably below that found in the average of English agricultural land. For instance, 0.05 per cent. of nitrogen may be considered as inadequate by the usual standard in England but in India some of the good soils even may not contain more than 0.05 per cent. On the other hand lime and potash are generally in sufficient quantities in Indian soils. The presence of lime helps to a great extent in counter-balancing the deficiencies of nitrogen and phosphoric acid. The lime by its presence makes the existing nitrogen,

potash and phosphoric acid more available to plants than they would otherwise be. On account of these reasons the standards for Indian soils may slightly differ from those for the English and American soils. The following table will indicate roughly the standards that may be taken for the soils of the Bombay Presidency with which this Bulletin is concerned. It must at the same time be borne in mind that these are approximates:—

•TABLE No. 1.

	Rich.	Good.	Fair.	Poor.
	More than Per cent.	Per cent.	Per cent.	Less than Per cent.
Nitrogen	0.1	0.06 to 0.1	0.03 to 0.06	0.03
Phosphoric acid—				
For non-clayey soils ..	0.1	0.06 to 0.1	0.03 to 0.06	0.03
For clayey soils ..	0.2	0.1 to 0.2	0.05 to 0.1	0.05
Potash—				
For non-clayey soils ..	0.25	0.15 to 0.25	0.05 to 0.15	0.05
For clayey soils ..	0.3	0.2 to 0.3	0.07 to 0.2	0.07
Lime	2.0	0.5 to 1.5 or 2.0	0.1 to 0.5	0.1

In good soils lime magnesia ratio should ordinarily show excess of lime over magnesia.

Available Potash and Phosphoric Acid.—Available potash and phosphoric acid should be present to the extent of at least 0.005 per cent. to be adequate.

Soluble Salts.—Plants take up mineral matter in the form of soluble salts. The percentage of the soluble salts in the soils must, however, be very small. Usually in good soils the total soluble salts do not exceed 0.1 per cent. If the quantity goes higher up the plants begin to suffer in health in proportion to the soluble salts present. There are certain salts which are distinctly harmful and in a good soil they should not be present at all. These salts in the order of their harmfulness are (1) sodium carbonate, (2) sodium bicarbonate, (3) sodium sulphate and besides these, calcium chloride, magnesium chloride and sodium chloride, etc. Calcium carbonate or sulphate when within the limits of 0.1 per cent. total soluble salts are quite good.

The harmful salts are bad even in small quantities. If the soils are of well-drained nature plants may grow in them with traces of sodium carbonate but any quantity approaching 0.01 per cent. indicates bad condition of the soil. Sodium bi-carbonate may go up to 0.01 per cent. and sodium sulphate up to 0.02 or in certain cases even up to 0.03 per cent. These are the limits and the crops grown with these quantities of the above salts will not be good. Naturally in well-drained soils plants may tolerate more salts than in clayey soils. Different types of plants differ in their power of resisting the bad effects of soluble salts. In Sind 0.5 per cent. of total soluble salts are found to be tolerated by

plants. In Western India experience tells us that sodium chloride is tolerated by plants in much larger quantities than would be ordinarily conceived. Recent experiments in Sind have shown that soils containing sodium sulphate are improved by the addition of calcium chloride. This must be due to the formation of calcium sulphate which improves the physical condition of the soil and of sodium chloride which is not so harmful as sodium sulphate. The following will give an idea about the total salts tolerated by the various plants in the Bombay Deccan. Some of the salt-loving grasses and woods as also the *babul* plant (*Acacia arabica*) tolerate very high quantities—over 1 per cent. of salts. Wild dates, beet root, etc., stand up to one per cent. Sugarcane, barley, salt rice are some of the cultivated crops that stand salts over 0.2 or even 0.3 per cent.

Mechanical Constituents.—In the case of mechanical analysis the classification adopted is as follows:—

TABLE NO. 2.

No.	Time taken by soil particles to settle down.	Nomenclature of soil separates.	Mean diameter of the soil particles in millimeter.
1	More than 24 hours	Clay ..	Below 0.001mm.
2	More than 2 hours and less than 24 hours.	Finest silt ..	0.001 to 0.022 mm.
3	More than half an hour and less than 2 hours.	Fine silt ..	0.002 to 0.01 mm.
4	More than 10 minutes and less than half an hour.	Medium silt ..	0.01 to 0.03 mm.
5	More than 75 seconds and less than 10 minutes.	Coarse silt ..	0.03 to 0.07 mm.
6	Particles passing through a sieve of 90 meshes to an inch.	Fine sand ..	0.07 to 0.2 mm.
7	Particles not passing through a sieve of 90 meshes to an inch.	Coarse sand ..	0.2 to 1 mm.

The properties of some of the fractions are indicated below as they will be of great use in interpreting the results of mechanical analyses. They have been extracted from "Soil Condition and Plant Growth" by E. J. Russell (Fifth edition).

Clay has great retentive properties and is therefore of great importance to the fertility of the soil, and no constituent is more necessary in proper proportions, or more harmful in excess. In general 8 to 16 per cent. is a satisfactory proportion of clay in a soil where the rainfall is 20 to 30 inches.

In fine silt the cohesiveness and power of holding water are considerable. Soils containing more than 15 to 20 per cent. of fine silt are often difficult to work.

Coarse silt appears to be very valuable. Probably silt plays an important part in maintaining the even conditions of moisture so

desirable for plant growth. It is fine enough to retard, but not to prevent, percolation, and it facilitates capillary movement of water.

Fine sand particles have some power of holding water and a certain degree of cohesiveness causing the particles to cake together. But the holding and retentive capacity is small as compared to finer fractions. Coarse sand exercises a great influence on soil fertility, largely through the negative nature of its properties. As the amount of coarse sand increases it becomes less and less suited for cultivation.

The percentage figures of the first four separates are added together and put under the common term "clay" which means particles that have retentive power for water and manurial constituents while the percentage figures for the remaining when added together give us material which is poor in retentive power.

The soils may be classified according to the proportion between clay and sand in the following way :—

TABLE NO. 3.

	Clay.	Sand.
	Per cent.	Per cent.
Sandy soil	10 to 20	80 to 90
Clay soil	50 or more	50 or less
Sandy loam	20 to 25	75 to 80
Loam	30 to 35	65 to 70
Clay loam	40 to 50	60 to 50

Mr. V. A. Tamhane, Agricultural Chemist and Soil Physicist at Sakrand has followed this classification in his Bulletin on the Salt Lands in Sind (Bulletin No. 96 of 1920, Bombay Department of Agriculture).

pH value interpretation.—The pH values give the reaction of the soils. Normal soils have pH value between 7 and 8·5. pH value lower than 7 indicates acidity. Those lower than 6·5 distinctly show their bad effect on crops.

Arrangement of Chapters.

The general arrangement of the information with regard to the soils of the Bombay Presidency, which is included in this bulletin is as follows. Chapter II is devoted to the soils of the Presidency as a whole. The geological classification is given first and then the chemical and mechanical analyses of certain typical soils of the Presidency are dealt with. A few other points regarding these soils are also mentioned there. In the chapters which follow the soils are dealt with by districts and a separate chapter is devoted to each Division. The Sind soils, however, are mentioned only in Chapter II under general soils but not in details by districts. In dealing with soils district by district the information given in Statistical Atlas and the Gazetteers has been fully drawn upon. Description with regard to area, physical features and rocks of the districts are given as they throw a good deal of light on the character of the soils.

In the analytical tables certain expressions are used and their exact meaning is given below to avoid confusion :—

Iron oxide	..	..	..	= $F_{e_3}O_3$
Alumina	..	..	..	= Al_2O_3
Lime	..	..	..	= C_aO
Magnesia	..	..	..	= M_gO
Potash	..	..	..	= K_2O
Soda	..	..	..	= Na_2O
Phosphoric acid	..	..	• •	= P_2O_5

CHAPTER II.

SOILS OF THE BOMBAY PRESIDENCY AS A WHOLE.

The soil is the formation on which the superstructure of agriculture is erected. It is ordinarily defined as the layer of more or less disintegrated rock, which covers a large portion of the surface of the earth and which is fitted, under suitable climatic conditions, to support the growth of plants. In addition to the mineral constituents, which usually form the largest portion, all soils contain some quantity of organic matter resulting from decay of previous vegetable growth. Soil also contains varying quantities of water, gases and living organisms.

A full knowledge of the soil includes the study of the soil from several points of view—the geological, chemical, physical or mechanical and biological.

There is very little information available as to the details of the physical properties of the soils of the Bombay Presidency and practically there is no information about the biological conditions of these soils. Our information is chiefly restricted to the geological classification and the chemical and mechanical analyses.

I.—Classification of soils according to geological formation and geographical situation.

The soils of the Bombay Presidency can conveniently be considered according to the divisions. Beginning from Sind which is the northernmost division of the Bombay Presidency and which is covered with the recent formation of the Indo-Gangetic alluvium we might proceed southward towards the Karnatic which is the southernmost part of the Presidency and is covered with the oldest rock formation.

Sind Soils.—Sind consists of the valley of the lower Indus and comprises three distinct tracts the Kohistan, or hilly country, on the extreme west, the central alluvial plain, watered by the Indus and the Thar or desert, on the eastern border. The central plain is the most important portion. The soils of this portion are entirely alluvial. They vary in character from drift sands to stiff clays. In some places the soil is very rich especially where tracts are covered with silt-laden waters.

The alluvial tracts on each side of the Indus are annually submerged in the inundation season and large areas which are covered by spilt-water retain sufficient moisture, after the flood subsides, to grow good

crops without irrigation. The silt deposited by canal water on arable fields is of immense value. At some places the Sind soils show formation of salt incrustation on the soils making them unfit for cultivation. These soils are called *Kalar*. The salts are not due, in many cases to water-logging but are due to the downward and upward movement of water, which leaves the dissolved salts behind on evaporation. This happens on account of scanty rainfall. It is only in a few cases that the *Kalar* is developed due to water-logging.

Gujarat Soils.—Gujarat can be divided into three tracts according to the soils it contains. These are: (1) The Panch Mahal tract, (2) The Northern Gujarat tract and (3) The Southern Gujarat tract.

The Panch Mahal tract stands by itself in the alluvial land of Gujarat. The predominant rocks there are granites and gneisses and therefore, as expected the soils are light coloured, shallow and poor, while in the low-lying areas, deep, rich dark coloured loams, retentive of moisture are common. These loamy soils can give two crops in a year. Usually there is maize in the *Kharif* season and wheat in the *robi* season.

In the North Gujarat tract consisting of Ahmedabad and Kaira districts the soil is alluvial of the Indo-Gangetic type and is called *Goradu* soil. *Goradu* soils are characterised by immense depth. They are distinctly sandy in character, varying from drift sands of the Ahmedabad district to the rich loams of Kaira. They vary in colour from light ash to rich brown. These soils do not crack. They are very suitable for irrigation and much of the best well-irrigation of the Presidency is on this land. Along the rivers there are soils called *Bhatha* formed from silt.

The southern Gujarat tract comprises the Broach and Surat districts. The soils of this tract are (1) the deep black soils, (2) the *bhatha* soils, (3) the *Gorat* soils and (4) the *Kiari* soils. All these soils are of alluvial character. They are however not of the Indo-Gangetic type. The main source of the deep black soils of Broach and Surat is trap with a little granite or gneiss. The colour of the soils is black and they are very deep. They are the black cotton soils. They are also known as *regar*. The *bhatha* soils are red, brown or chocolate in colour. They are alluvium deposited by rivers during high floods. The fertility of these soils may be renewed every year by fresh silt. These soils are found in belts along the Tapti and Narbuda banks. The *bhatha* soils grow excellent irrigated crops. Old *bhatha* soils are found sometimes away from the present rivers. They are called *gorat* soils. They are alluvial in character and are suited for irrigation. *Kiari*s are rice soils in low-lying areas, receiving drainage from the surrounding country.

The Deccan Tract Soils.—The Deccan is made up of the following Districts:—East and West Khandesh, Nasik, Poona, Satara, Ahmednagar and Sholapur. The soils of all these districts are entirely derived from trap. The Khandesh soils form one group and the rest of the Deccan has three north-south strips of soils parallel to the Western Ghats.

The Khandesh soils are black cotton soils and hence they are generally very deep and retentive especially those that form the flat areas along the Tapti river. The crops taken on these soils are cotton, *jowar* and wheat.

Black cotton soil is a term applied to deep black clayey soils found generally below the level of the foot-hills. It is formed by the washing of the disintegrated material from a higher level. In the third volume of the Imperial Gazetteer the black cotton soils are described as follows :—
 “Black cotton soil occurs within the area of the Deccan trap in undulating or sloping situations, below the general level of the foot-hills. It varies in depth according to position and, where very deep, has been accumulated by alluvial deposit. In places in the valley of the Tapti, the Narbuda, the Godavari and the Krishna, heavy black soil is often 20 feet in depth. Owing to its dense consistence it becomes unworkable during heavy rains, and in these places, is better adapted for *rabi* crops of wheat, linseed, gram, etc., than for cultivation in the *kharif* season. The black cotton soil of the Deccan trap area which grows cotton and *jowar* as staple crops in the *kharif* season, is, as a rule, only three or four feet deep and is mixed with nodular pieces of lime-stone and small fragments of disintegrated trap. The sub-soil contains a good deal of lime, and being shaly allows free drainage to the trap rock below. Black soils vary in colour, consistence, and fertility, but all are highly retentive of moisture. In the hot weather shrinkage due to evaporation causes the formation of numerous cracks which are often several feet deep. This feature has given origin to the common saying ‘Black soil ploughs itself.’ The deeper black cotton soils are entirely unsuitable for irrigation; but the mixed black soil found in the smaller valleys when it is of moderate depth and the substratum affords good natural drainage, admits of well-irrigation and produces under liberal cultivation all kinds of garden crops. The depth to the sub-soil water in these situations is usually 25 to 30 feet. Outside the Deccan trap area the black cotton soil predominates in Surat and Broach districts.”

The remaining portion of the Deccan districts may be divided into (1) the high lying strip along the western Ghats—hilly in character with heavy rainfall and having soils of a very shallow character. On these soils rice and small millets are grown on terraces, (2) A strip of country which is less hilly, and has sufficient and certain rainfall is the second. Soil in this part is not very deep. Both *kharif* and *rabi* crops as also irrigated crops are taken in this strip, (3) The third is the easternmost strip of the Deccan which has uncertain rainfall. This part has got deep black soils which are retentive and with enough rainfall they give excellent crops. The wheat lands of Nasik and of Kopergaon in Ahmednagar, *rabi jowar* lands of Ahmednagar and Sholapur, are black soils. The divisions of soils shown above are very rough. These soils are all from trap. They simply indicate the stage of decomposition of the rock and the nature of accumulation of the soil. Even in one village we may meet with all types of soils.

Near Ghats the proportion of the shallow soils will be great with only a small area, if at all, under black soils while in the eastern strip the

proportion of the black and deep soils will bear a high proportion to the shallow soils.

There are soils found on the river banks which are suitable for garden crops. Along the canals in some places salt lands have developed in recent years. The cause is invariably the rise of subsoil water which is not drained away on account of impervious layers at depths varying from a foot or two to seven or eight feet. The salt lands are unfit for cultivation as the salts prove to be poisonous to plants.

In some parts of Ahmednagar and Sholapur districts numerous round stones of varying size are found in the fields. The soils in which these stones are found are fine in texture and fairly fertile. The stones are brought up by tillage. They slowly decompose into soil and are in no way troublesome to the crop.

The Konkan Soils.—Thana and Kolaba districts have trap soils. Ratnagiri has laterite soils. On the northern side the laterite is over the trap while on the southern side it is over the gneiss. Soils of Kanara are derived from a variety of rocks, such as granites, gneisses, laterite, etc. The whole Konkan is hilly and has thin and porous soils. Near the coast we meet with some deeper soils on level land. The soils in general are divided into, (1) *Varkas* soils, (2) rice soils and (3) garden soils.

The varkas soils occupy the uplands. They are very thin and poor. They are allowed to waste periodically. After the rest there is a rotation of crops. Inferior millets, niger, etc., are the usual crops.

Rice Soils which are low-lying called *mala* while those which are on the uplands and slopes with terraces are of a poorer character. They are known as *Kuryat*. There are some lands recovered from sea. They are saltish and therefore people grow salt rice on such lands. They are called *Kharvat*.

Garden lands are found along the coast in the Thana district. They have light, easily workable soils. Various kinds of garden crops are grown on them. Practically there are no deep clayey soils along the coast line and at many places garden crops can be grown if water in good quantity is available.

North Kanara is the southernmost district of Konkan. On the top of the Ghats and uplands, the soil is laterite. Much of the land is under forest. Rice is grown where land has been cleaned. In the valleys between hills there are gardens growing betelnut, cardamom and pepper, etc. The soils of these gardens are derived from shales. Where these valleys open out rice is the chief crop grown. The coast line is covered with soil derived from low-level laterite or decomposing gneisses. The soils of the North Kanara vary from yellowish to red in colour. They are well drained and porous and in places very hungry. They are poor in lime and phosphoric acid.

Karnatak Soils.—Three districts are included in Karnatak—Belgaum, Dharwar and Bijapur. The Belgaum district has granite and gneiss formation on its southern side where it meets the boundaries of Dharwar

or North Kanara, sandstone formation in its eastern part where it meets Bijapur and on the northern and western side it has trap, in many places covered with laterite. The soils of the Belgaum district naturally vary very much. The soils derived from only laterite or only sandstone are very porous and also poor. Where the laterite or sandstone soils are mixed with trap soils they make a very good mixture and produce excellent crops. Near Belgaum the soils are formed by a mixture of material derived from both the laterite and trap. These soils are rich, and grow rice and all sorts of vegetables. They are very good for irrigated crops. Dharwar and part of Bijapur contain soils derived from granites and gneisses as also from schists belonging to the transition formation. The soils vary very much in their character. They vary from coarse, sandy and shallow soils to clays which are several feet deep. With good rainfall the deep soils grow excellent crops of cotton and *jowar* and also wheat.

II.—Chemical Analyses.

The following are the chemical analyses of the typical soils of the Bombay Presidency.

Sind Soils.—The majority of Thar Parkar soils differ from the soils of the other tracts of Sind although they are all alluvial in nature. The Thar Parkar soils have as high a per cent. of silica and insoluble silicates as 88 to 90. They are low in loss on ignition and in lime. The magnesia is higher than or nearly equal to lime in these soils. The other soils are rich in lime, good to rich in potash, fair to good in phosphoric acid, and fair in nitrogen—

TABLE NO. 4.

	Kohistan tract.		Central Alluvial plain.		Thar Parkar.	
	Surface Soil.	Subsoil.	Surface Soil.	Subsoil.	Surface Soil.	Subsoil.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Moisture ..	0.38	0.54	0.80	0.72	0.42	0.52
Loss on ignition ..	3.78	4.40	5.40	4.34	1.84	2.06
Silica and insoluble silicates ..	73.90	72.34	74.82	76.28	90.52	88.40
Lime as CaO ..	8.18	8.01	3.36	3.92	0.28	0.56
Magnesia as MgO ..	0.50	0.50	0.40	0.50	0.40	0.50
Potash as K ₂ O ..	0.17	0.31	0.29	0.31	0.19	0.15
Phosphoric acid as P ₂ O ₅ ..	0.06	0.07	0.15	0.15	0.11	0.12
Nitrogen ..	0.064	0.054	0.048	0.028	0.043	0.043
PH value ..	8.6	8.7	8.6	8.7	8.6	8.4

Gujerat Soils.—The Gujerat soils which are mostly of alluvial origin are not all of the same nature. Goradu soils are the most important. They are sandy and yet fair in nitrogen, rich in lime, potash and phosphoric acid. The Bhattha soils are considered as an old alluvial. In

North Gujerat they are good in nitrogen and rich in lime, potash and phosphoric acid. The Bhatha soils of South Gujerat differ from those of North Gujerat inasmuch as they contain lower proportions of lime and phosphoric acid. The gorat soils are on the whole poor in nitrogen and fair in other constituents. The black cotton soils are good in the plant food constituents—

TABLE NO. 5.

Soils from North Gujerat.

	Sandy Goradu.		Bhatha Soils.	
	Village Keliawana, Taluka Dholka.	Village Kelia.	Fatewad.	Taluka Daskroi.
	Surface Soil 1" to 6".	Subsoil 7" to 12".	Surface Soil 1" to 6".	Subsoil 7" to 12".
	Per cent.	Per cent.	Per cent.	Per cent.
Moisture ..	1.34	1.38	2.42	2.00
Loss on ignition ..	4.06	3.60	6.74	5.90
Silica and insoluble silicates ..	80.58	81.50	69.66	73.64
Lime as CaO ..	2.638	3.086	4.20	3.758
Magnesia as MgO ..	0.50	0.50	0.30	0.30
Potash as K ₂ O ..	0.502	0.483	0.559	0.425
Phosphoric acid as P ₂ O ₅ ..	0.170	0.115	0.153	0.126
Nitrogen ..	0.056	0.043	0.089	0.097
PH value ..	8.2	8.5	9.2	9.2

TABLE NO. 6.

Soils from South Gujerat.

	Bhatha Soils.		Gorat Soils.		Black Cotton Soils.	
	Surface Soil.	Subsoil.	Surface Soil.	Subsoil.	Surface Soil.	Subsoil.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Moisture ..	2.56	3.42	4.20	3.84	6.40	6.44
Loss on ignition ..	5.68	4.84	4.20	5.04	7.60	7.78
Silica and insoluble silicates ..	73.46	73.62	68.94	70.24	60.72	61.06
Lime as CaO ..	0.286	0.286	0.398	0.342	0.398	0.734
Magnesia as MgO ..	0.50	0.80	0.60	0.60	0.90	1.30
Potash as K ₂ O ..	0.115	0.212	0.097	0.193	0.077	0.116
Phosphoric acid as P ₂ O ₅ ..	0.085	0.093	0.085	0.070	0.074	0.133
Nitrogen ..	0.078	0.07	0.038	0.024	0.051	0.054
PH value ..	8.2	8.3	8.2	8.3	8.0	8.0

The Deccan Trap Soils.—These soils contain a high proportion of loss on ignition due to the clayey character. They are all good to rich in lime, and vary in their potash, phosphoric acid, and nitrogen contents. They may be said to be fairly good in plant food constituents—

TABLE NO. 7.
Soils from Khandesh Districts.

	Dhulia. • •		Jalgaon.	
	Surface Soil 1' to 6'.	Subsoil 7' to 12'.	Black cotton surface soil.	Black cotton subsoil.
	Per cent.	Per cent.	Per cent.	Per cent.
Moisture	7.76	8.10	8.72	9.14
Loss on ignition	9.16	9.18	9.20	10.00
Silica and insoluble silicates	64.00	62.64	60.14	60.34
Lime and CaO	1.63	1.126	2.69	4.206
Magnesia as MgO	0.50	0.50	0.20	0.40
Potash K ₂ O	0.174	0.405	0.19	0.58
Phosphoric acid as P ₂ O ₅	0.080	0.070	0.088	0.104
Nitrogen	0.110	0.064	0.11	0.059
PH value	8.1	8.1	8.0	8.1

TABLE NO. 8.
Deccan Trap Soils—Poona District.

	Deep Black Soil		Medium Black Soil.	Murmad Soil.
	Surface soil 0' to 9'.	Subsoil 9' to 18'.		
	Per cent.	Per cent.	Per cent.	Per cent.
Loss on ignition	19.2	20.6	11.4	8.06
Silica and insoluble silicates	63.8	65.7	58.40	79.96
Iron and Alumina .. ..	.....	.....	18.40	.....
Lime as CaO	1.90	1.40	4.00	0.80
Magnesia MgO .. ..	.....	.....	1.60	.....
Potash K ₂ O	1.60	0.80	0.40	0.93
Phosphoric acid P ₂ O ₅	0.23	0.42	0.080	0.11
Nitrogen	0.06	0.05	0.05	0.05

TABLE NO. 9.

Laterite Soil—Belgaum District.

	Surface Soil	Subsoil
	1' to 6'.	7' to 12'.
	Per cent.	Per cent.
Moisture	6.20	5.80
Loss on ignition	8.30	10.12
Silica and insoluble silicates	98.8	50.70
Lime as CaO	0.174	0.174
Magnesia as MgO	0.30	0.30
Potash as K ₂ O	0.270	0.251
Phosphoric acid as P ₂ O ₅	0.281	0.322
Nitrogen	0.110	0.170
PH value	7.8	7.7

TABLE NO. 10.

Granite Soils—Dharwar District.

	Granite Soil.
Moisture .. .. .	..
Loss on ignition	5.00
Silica and insoluble silicates	79.53
Iron and Alumina	13.05
Lime as CaO	0.59
Magnesia M ₂ O	0.55
Potash K ₂ O	0.27
Phosphoric acid P ₂ O ₅	0.08
Nitrogen	0.064
PH value .. .. .	....

Interpretation of the analytical figures given in the previous tables.

TABLE NO. 11.

	Nitrogen.	Phosphoric acid P ₂ O ₅ .	Potash K ₂ O.	Lime CaO.
<i>Sind Alluvial.</i>				
Kohistan tract—				
Soil	Fair	Good	Good	Rich
Subsoil	Do.	Do.	Rich	Do.
Central alluvial plane—				
Soil	Fair	Rich	Rich	Rich
Subsoil	Poor	Do.	Do.	Do.
Thar Parkar—				
Soil	Fair	Rich	Good	Fair
Subsoil	Do.	Do.	Do.	Do.

TABLE NO. 11—contd.

	Nitrogen.	Phosphoric acid P ₂ O ₅ .	Potash K ₂ O.	Lime CaO.
<i>Sind Alluvial—contd.</i>				
North Gujerat—				
Goradu Soil	Fair	Rich	Rich	Rich
Goradu Subsoil	Do.	Do.	Do.	Do.
Bhatha Soil	Good	Do.	Do.	Do.
Bhatha Subsoil	Do.	Do.	Do.	Do.
South Gujerat—				
Bhatha Soil	Good	Good	Rich	Fair
Bhatha Subsoil	Do.	Do.	Do.	Do.
Gorat Soil	Fair	Do.	Good	Do.
Gorat Subsoil	Poor	Do.	Rich	Do.
Black cotton—				
Soil	Fair	Fair	Fair	Fair
Subsoil	Do.	Good	Do.	Good
Khandesh Districts—				
Dhulha—				
Soil	Rich	Fair	Fair	Good
Subsoil	Fair	Do.	Rich	Do.
Jalgaon—				
Soil	Rich	Fair	Fair	Rich
Subsoil	Fair	Good	Rich	Do.
Deccan Trap area—				
Deep black—				
Soil	Fair	Rich	Rich	Good
Subsoil	Do.	Do.	Do.	Do.
Medium black—				
Soil	Fair	Good	Rich	Rich
Murmad Soil	Do.	Do.	Do.	Good
Belgaum—				
Laterite Soil	Rich	Rich	Rich	Fair
.. Subsoil	Do.	Do.	Do.	Do.
Dharwar—				
Granite Soil	Fair	Good	Rich	Fair

The Lime Magnesia Ratio.

In Sind soils the lime magnesia ratio is quite good except in the soils of Thar Parkar. In Thar Parkar soil the ratio is as 3 : 4 or 1 : 1, while for other soils the ratio varies from 8 : 1 to 16 : 1. For North Gujerat the ratio is from 5 : 1 to 14 : 1. For South Gujerat however it is as 1 : 1.5 to 1 : 2.6 which means in these soils magnesia is in excess of the lime. For Deccan soils the ratio is from 2 : 1 to 13 : 1.

Loss on Ignition.

The loss on ignition indicates organic matter and also water retentive power of the soil. In this respect the Thar Parkar soil from Sind is poor showing about two per cent. of loss on ignition. The other soils from Sind and the sandy soils of Gujerat have loss on ignition varying from 4 to 6 per cent. The black cotton soil of Broach contains 7.6 per cent.

The Khandesh soils have loss on ignition between 9 and 10 per cent. while the medium black soils of the Deccan show loss on ignition up to 12 per cent. and deep black soils up to 20 per cent.

The PH Values.

The PH values of most of the soils in the Bombay Presidency are between 8 and 9. The laterite soils of Belgaum have the PH value somewhere about 7.7.

III.—Mechanical Analyses.

The following tables give the mechanical analyses of the typical soils of the Bombay Presidency:—

TABLE No. 12.

Soils from Sind.

	Kohistan tract.		Central alluvial plane.		Thar Parkar.	
	Surface.	Subsoil.	Surface.	Subsoil.	Surface.	Subsoil.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Clay and finest silt ..	8.89	7.84	15.67	15.43	5.23	10.71
Fine silt ..	1.70	2.12	8.52	5.90	0.74	1.44
Medium silt ..	0.39	1.76	7.88	7.60	0.40	0.26
Coarse silt ..	2.21	3.94	48.23	49.37	1.93	2.24
Fine sand ..	35.15	44.74	19.52	21.50	30.41	25.12
Coarse sand ..	51.66	39.60	0.18	0.20	61.29	60.23
	100.00	100.00	100.00	100.00	100.00	100.00

TABLE No. 13.

Soils from North Gujerat.

	Sandy Goradu.		Bhatha Soil.	
	Soil 1' to 6".	Subsoil 7" to 12".	Soil 1' to 6".	Subsoil 7" to 12".
	Per cent.	Per cent.	Per cent.	Per cent.
Clay and finest silt ..	11.47	12.96	15.22	12.28
Fine silt ..	7.44	8.77	8.95	6.80
Medium silt ..	8.34	9.42	12.18	8.91
Coarse silt ..	10.52	8.80	24.19	18.59
Fine sand ..	31.65	27.34	26.18	47.93
Coarse sand ..	30.58	32.71	3.37	5.46
	100.00	100.00	100.00	100.00

TABLE No. 14.
Soils from South Gujerat.

	Bhatha.		Gorat.		Black Cotton.	
	Soil.	Subsoil	Soil.	Subsoil	Soil.	Subsoil.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Clay and finest silt.	17.43	15.97	14.03	14.33	44.36	52.63
Fine silt ..	3.87	4.02	3.28	2.58	8.08	7.12
Medium silt ..	8.96	8.10	5.80	5.09	11.84	9.68
Coarse silt ..	24.07	22.49	11.47	12.05	14.65	11.17
Fine sand ..	39.16	44.33	63.85	64.92	20.70	18.35
Coarse sand ..	6.51	5.09	0.67	1.03	0.37	1.05
	100.00	100.00	100.00	100.00	100.00	100.00

TABLE No. 15.
Khandesh Districts.

	Dhulia.		Jalgaon.	
	Surface Soil 1" to 6".	Subsoil 7" to 12".	Surface Soil 1" to 6".	Subsoil 7" to 12".
	Per cent.	Per cent.	Per cent.	Per cent.
Clay and finest silt ..	45.46	47.12	49.15	51.04
Fine silt ..	4.56	4.68	3.99	5.64
Medium silt ..	6.15	6.40	6.34	7.46
Coarse silt ..	12.84	12.14	10.76	9.87
Fine sand ..	26.52	25.58	25.61	24.47
Coarse sand ..	4.47	4.08	4.15	1.53
	100.00	100.00	100.00	100.00

TABLE No. 16.
Deccan Trap Soils—Poona District.

	Deep Black.		Medium Black Soil.	Murmad Soil.
	Soil.	Subsoil.		
	Per cent.	Per cent.	Per cent.	Per cent.
Clay and finest silt ..	4.8	5.7	17.94	3.11
Fine silt ..	61.2	60.6	9.09	3.07
Medium silt ..	10.7	13.7	11.17	4.21
Coarse silt ..	8.4	7.5	13.75	11.35
Fine sand ..	8.2	7.7	43.82	60.77
Coarse sand ..	6.7	5.8	4.23	17.48
	100.00	100.00	100.00	100.00

TABLE No. 17.

Laterite Soils—Belgaum District.

	Surface soil	Sub-soil
	1' to 6".	7' to 12".
	Per cent.	Per cent.
Clay and finest silt	43·36	31·46
Fine silt	5·14	4·68
Medium silt	10·66	8·56
Coarse silt	9·27	13·56
Fine sand	18·27	22·02
Coarse sand	13·30	19·79

TABLE No. 18.

Granite Soils—Dharwar District.

	*Granite soil
	Per cent.
Clay and finest silt	30·00
Fine silt	7·00
Silt	2·00
Fine sand	9·40
Coarse sand	43·20

* Mechanical analysis by International method.

The soils whose mechanical analyses are given above can be classified as follows:—

TABLE No. 19.

	Clayey portion.	Sandy portion.	Class of soil.	Maximum water-holding capacity.	Capillary rise of water in 7 days.
<i>Sind.</i>	Per cent.	Per cent.		Per cent.	
Kohistan tract—					
Soil	10·98	89·02	Sandy .. .. .	.. .. .	.. .. .
Sub-soil	11·72	88·38	Do. .. .. .	.. .. .	.. .. .
Central alluvial tract—					
Soil	22·07	67·93	Sandy loam .. .. .	.. .. .	.. .. .
Sub-soil	28·93	71·07	Do. .. .. .	.. .. .	.. .. .
Thar Parker—					
Soil	6·37	93·63	Sandy .. .. .	.. .. .	.. .. .
Sub-soil	12·41	87·59	Do. .. .. .	.. .. .	.. .. .
North Gujerat.					
Sandy Goradu—					
Soil	27·25	72·75	Sandy loam	53·26	3·7"
Sub-soil	31·15	68·85	Loam .. .. .	.. .. .	.. .. .
Bhatha Soil	36·35	63·65	Do. .. .. .	.. .. .	.. .. .
Sub-soil	27·99	72·03	Sandy loam .. .. .	.. .. .	.. .. .

TABLE No. 19—*contd.*

	Clayey portion.	Sandy portion.	Class of soil.	Maximum water- holding capacity.	Capillary rise of water in 7 days.
<i>South Gujerat.</i>					
	Per cent.	Per cent.		Per cent.	
Bhatha soil ..	30·26	69·74	Loam ..	..	..
Sub-soil ..	28·09	71·91	Sandy loam ..	..	..
Gorat Soil ..	24·01	75·99	Do. ..	..	..
Sub-soil ..	22·00	78·00	Do. ..	..	..
Black cotton—					
Soil ..	64·28	35·72	Clay soil ..	70·52	1'8"
Sub-soil ..	69·43	30·57	Do. ..	..	..
<i>Khandesh Districts.</i>					
Dhulia soil ..	56·17	43·83	Do. ..	..	..
Sub-soil ..	58·20	41·80	Do. ..	..	..
Jalgaon soil ..	59·48	40·52	Do. ..	..	..
Sub-soil ..	64·13	35·87	Do. ..	..	..
<i>Poona District.</i>					
Deep black soil ..	76·7	23·3	Do. ..	88·45	1'9"
Sub-soil ..	80·0	20·0	Do. ..	..	..
Medium black soil ..	38·29	61·80	Loam ..	..	..
Murmad soil ..	10·39	89·61	Sandy soil ..	56·8	3"
<i>Karnatak.</i>					
Belgaum district—					
Laterite soil ..	44·70	55·30	Clay loam ..	..	2'9"
„ Sub-soil ..	59·16	40·84	Clay soil ..	..	..
Dharwar District—					
Granite soil ..					
„ Sub-soil ..					

IV.—Alkali Soils.

Alkali soils are met with here and there all over the Presidency but the newly developed salt lands which have been badly affected are in the Deccan.

The Deccan Salt Lands.—In the Eastern part of the Bombay Deccan there are areas which are dry and famine-stricken but they possess deep and black soils in many parts. In order to give relief to the agriculturists of these parts canals were constructed. Not long after the canals began to flow it was observed that some of the best soils developed salt incrustation and began to be barren. The improvement of such salt lands has become a great problem and is being tackled by a special officer. A very large number of affected soils and the waters in them were analysed in the chemical laboratory of the Agricultural Department. The analytical figures show that the top six inch layers of the soils contain soluble salts varying from 1·5 to 3·5 per cent. The salts are white coloured and contain sodium sulphate varying from 0·6 to 1·6 per cent. Sodium carbonate is found only

in a few samples and that too is present in small quantities. The following table will give a clear idea as to the soluble total and individual salts at different depths in the salt-affected soils in the canal areas of the Bombay Deccan.

TABLE No. 20.

Analysis of soil samples from Nira Left Bank Canal.

	0-6"	6-12"	12-18"	18-24"	24-30"	30-36"	36-42"	42-48"
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Stones ..	24.5	31.5	36.5	40.5	43.2	33.7	46.3	45.6
Total soluble salts ..	3.050	0.970	0.940	0.830	0.450	0.470	0.430	0.460
Calcium carbonate ..	0.029	0.039	0.036	0.036	0.020	0.020	0.048	0.010
Calcium sulphate ..	0.680	0.013	0.040	0.035	..	..	0.030	..
Magnesium carbonate ..	..	..	..	..	0.0154	0.0158	..	0.015
Sodium carbonate ..	..	..	0.005	0.005	..	..	..	..
Magnesium sulphate ..	0.176	0.033	0.022	0.022	0.011	0.011	0.044	..
Sodium bicarbonate ..	..	..	..	..	..	..	..	0.016
Sodium sulphate ..	1.570	0.680	0.738	0.609	0.313	0.296	0.211	0.266
Sodium chloride ..	0.439	0.115	0.069	0.069	0.057	0.057	0.57	0.080

Many of these soils are water-logged and a bore to a depth of two or three feet reaches the water level in the soil. The total salts in these waters are very high and may vary from 200 to 1,200 parts of salts per 100,000 parts of water. The salts found in the water are the same as those found in the soils.

Sometimes the fields while covered with encrustation show black patches. These are moist and contain calcium chloride.

In the improving of these lands, removal of salts by surface washing, addition of organic matter and draining of the lands have been found to be beneficial. The draining of the land is perhaps the most important. The drains however must be put sufficiently deep to allow the water held by the soil to run into the drains. This is possible only when the drains cut through the hard pans and are below them in depth. When the soils are fairly drained the addition of organic matter to the soil will help some crop to grow and slowly improve the soil.

The Salt Lands in Sind.—Investigation of these lands was carried out by Mr. V. A. Tamhane, who as Agricultural Chemist and Soil Physicist at Sakrand is still working on Sind soils. The figures which he has published in the Bombay Agricultural Department Bulletin No. 96 of 1920 show total soluble salts in the top six inches as varying from 0.3 to 3.00 per cent. One of the samples with a sufficiently high percentage of soluble salts contains the following proportions of the individual salts as given on page 46 of the Bulletin mentioned above.

TABLE No. 21.

			Surface 0-6"
			Per cent.
Total soluble salts	..	..	2.40
Containing—			
Calcium carbonate	..	..	0.03
Calcium sulphate	..	..	0.62
Magnesium sulphate	..	..	0.33
Sodium carbonate	..	..	0.01
Sodium bicarbonate	..	..	<i>Nil.</i>
Sodium sulphate	..	..	0.96
Sodium chloride	..	..	0.43

One surprising thing about the Sind salt lands is that the crops are found to tolerate comparatively very high proportions of salts under Sind conditions. Many plants grow in soils with 0.5 per cent. salts.

V.—Karl Soils of the Karnatic.

There are several areas in the Karnatic which are occupied by what are known as *karl* soils. The crops on these soils are inferior to those on good soils and with small rainfall the *karl* soils give but very little outturn. All the soils are not equally bad and hence they are grouped into classes :—(1) medium *karl* which is inferior to good soil but is better than hard *karl*, and (2) hard *karl* which is practically barren.

The following figures indicate the nature of the soils. They are very sticky with high quantities of soluble salts :—

TABLE No. 22.

	Medium <i>Karl</i> .		Hard <i>Karl</i> .	
	0-1'	1-2'	0-1'	1-2'
	Per cent.	Per cent.	Per cent.	Per cent.
Clay and finest silt	45.41	43.20	42.83	50.82
Fine silt	8.62	10.64	11.87	9.62
Medium silt	6.25	8.23	9.78	8.65
Coarse silt	12.00	16.34	16.50	15.39
Fine sand	17.80	16.77	15.00	11.76
Lime (CaO)	3.13	1.84	3.25	3.97
Total soluble salts	0.14	0.18	0.34	0.41
Sodium sulphate	0.035	0.029	0.139	0.16
Water holding capacity	86.38	98.97	93.02	102.35

VI.—Morik Soils.

In the Ratnagiri District there are some soils known locally as *morik*. They are found especially in the Vengurla Taluka. If the rainfall is

heavy the crop is nearly normal but if the rainfall is less than usual the crop suffers here much more than on other soils. The *morik* material rises to the surface in fair season. Its analysis was found to be as follows :—

TABLE No. 23.

		Per cent.
Soluble material	..	29.88
Containing—	• •	
Chlorine (Cl)	..	0.28
Sulphuric acid (SO ₃)	..	12.55
Iron oxide (Fe ₂ O ₃)	..	1.96
Alumina (Al ₂ O ₃)	..	2.84
Lime (CaO)	..	1.20
Magnesia	..	0.80

The soil is distinctly acidic. Patches of the *morik* type are found on coastal villages of North Kanara District. Rice does not grow well on these patches. The patches show a tendency to grow slowly in size. The crop in the seedling stage grows fairly well but after some time the plants begin to die. On these soils there is generally a slimy brownish substance in rains but in summer there is a sort of white encrustation. The surface scraping of these soils gives the following analysis :—

TABLE No. 24.

		Per cent.
Total soluble salts	..	0.30
Containing—		
Iron and Alumina	..	0.02
Lime	..	0.039
Magnesia	..	0.021
Sulphuric acid (SO ₃)	..	0.14
Chlorine (Cl)	..	0.031

All such soils show Ph. value from 5 to 5.8. These are improved by the addition of lime or bone-meal.

VII.—Manat Soils.

In the Kolaba and Thana districts in some places we meet with very sticky clayey soils, locally called *manat*. These *manat* soils are deep and clayey. They become nearly inaccessible during rains and crack heavily in the hot season. Some of these soils were analysed fully and the following are the analytical figures of typical *manat* soils.

TABLE NO. 25.

—	Top 6" Soil No. 1.	6" to 12" Soil No. 1.	Soil No. 2.	Soil No. 3.
	Per cent.	Per cent.	Per cent.	Per cent.
Loss on ignition	11.86	10.12 • •	12.88	13.32
Silica and Insoluble silicates ..	56.60	67.86	59.86	59.60
Iron oxide (Fe_2O_3)	15.20	18.41	13.40	12.40
Alumina (Al_2O_3)	15.00	11.99	13.00	14.00
Lime (CaO)	1.00	0.42	1.21	1.34
Potash (K_2O)	0.75	0.59	0.67	0.71
Phosphoric acid (P_2O_5)	0.038	0.042	0.048	0.058
Nitrogen	0.104	0.078	....	....
Organic matter	1.33	1.14	1.29	1.25

These soils contain very large proportions of iron and alumina and it was also found that they contain in many places rounded nodules containing manganese. The analysis of the modules is as follows :—

TABLE NO. 26.

	Per cent.
Silica and Silicates	38.52
Iron oxide (Fe_2O_3)	24.12
Alumina (Al_2O_3)	5.08
Manganese oxide (Mn_2O_3)	15.64

The soils contain a good amount of nitrogen and potash. They are fairly well in lime but have low phosphoric acid.

The mechanical separates which are given below show that they contain large quantities of clay and finest silt and also of fine and medium silt.

TABLE NO. 27.

—	Top 6" soil.	Soil 6" to 12"
	Per cent.	Per cent.
Clay and finest silt	23.96	26.24
Fine silt	19.77	19.72
Medium silt	22.95	18.89
Coarse silt .. ..	....	....
Fine sand .. ..	....	....
Coarse sand	10.22	11.83

Naturally therefore these soils are extremely sticky and clayey. These soils however do not contain any high proportions of soluble salts as will be seen from the following figures :—

TABLE NO. 28.

					Top soil 6"	Soil 6" to 12"
Ca	..	..	..	..	0·012	0·012
Mg	..	..	..	..	0·007	0·007
CO ₂	..	..	..	..	0·018	0·018
SO ₄	..	..	..	..	0·025	0·025
Cl	..	..	..	..	0·007	0·007

These soils may be improved by cultivation at a suitable time and by incorporating organic matter even such as the upper coats of rice seed.

CHAPTER III.

SOILS OF GUJERAT.

Gujerat has five districts. The Panch Mahals, Ahmedabad and Kaira districts form North Gujerat, while Broach and Surat form South Gujerat. Each of these districts is separately treated.

(A) Panch Mahals District.

Area.—The district of Panch Mahals lies between 22° 15' and 23° 11' north latitude and 73° 22' and 74° 29' east longitude and covers an area of 1,608 square miles.

Physical features and rainfall.—The western part is flat and the easter division is rugged. The rainfall in the western part is 38 to 44 inches while in the eastern part it is about 30 inches.

Rocks.—In the Western part near Godhra the rocks are metamorphic while in the south-west there is the trap with Pavagad as a prominent hill. A variety of rocks are found in the Panch Mahals District. They are trap, granite, schists, limestone, sandstone and quartzite.

Soils.—There are many varieties of soils found in this district. There is the light or sandy loam in the north-west of Godhra and in Kalol Taluka ; to the north and north-east of Godhra there is medium black soil which grows wheat and gram. In Kalol Taluka there are a few villages with medium black soil. In the south of Halol there are stretches of rich black soil. In the eastern part of the district both the light and black soils are of high quality.

The chemical analysis of the three typical soils is as follows :—

TABLE NO. 29.

					Sandy.	Medium Black.	Black.
					Per cent.	Per cent.	Per cent.
Loss on ignition	..	..	..	..	4·78	7·30	8·64
Silica and insoluble silicates	..	..	..	..	88·00	83·30	79·14
Lime	..	..	..	..	0·45	0·56	0·34
Potash	..	..	..	..	0·57	0·41	0·38
Phosphoric acid	..	..	..	..	0·31	0·19	0·21
Nitrogen	..	..	..	..	0·04	0·05	0·08

Sandy loam has but a small retentive power for moisture while the black soil retains a high percentage. The percentages for loss on ignition, nitrogen and sand indicate the differences in the three soils. As the insoluble silica and silicates decrease the loss on ignition and nitrogen increase, The soils are quite good in potash and phosphoric acid and fair in lime and nitrogen.

The mechanical analyses of the sandy and medium black soils are given in the table below :—

TABLE NO. 30. •

	Sandy.	Medium Black.
	Per cent.	Per cent.
Clay and finest silt	6.73	9.75
Fine silt	3.54	3.54
Medium silt	5.13	5.32
Coarse silt	9.77	8.92
Fine sand	67.98	61.21
Coarse sand	6.85	11.26

Even the medium black soil is practically sandy or at best a sandy loam.

(B) Ahmedabad District.

Area.—The district of Ahmedabad lies between 21° 26' and 23° 37' north latitude and 71° 19' and 73° 27' east longitude and covers an area of 3,816 square miles.

Physical features and rainfall.—In the extreme south and also just beyond the northern boundary, are a few rocky hills. But between these points the whole of the district forms a level plain gradually rising towards the north and east. The average rainfall of the district is about twenty-nine inches.

Soils.—There are two chief kinds of soils, the black or *kali* and the light or *goradu*. The black soil is found chiefly towards the west and the light soil in the east. The black has a subsoil of modular and stone and gravel. It is many times impregnated with salts. The light soils are well supplied with springs, which, after the early harvest has been reaped, enable the cultivators at very little cost to have cold weather, *rabi* and even hot weather crops. With the help of manure and water the light soil is very fertile. During dry weather it wears into a loose fine sand but when the rain falls it becomes tolerably compact. Two other varieties of soil deserve mention—an alluvial deposit of the Sabarmati river and a red stony soil. The alluvial deposit of the Sabarmati is the most fertile soil in the district, easily irrigated, holding water at the depth of a few feet below the surface. The stony soil good for growing maize is found in the north-east sub-division of Prantij.

The following figures bring out the differences in the different classes of soils of the Ahmedabad District. We shall first take typical individual soils and then have the variation as shown by each class with regard to chemical and mechanical analyses :—

TABLE NO. 31.
Chemical Analysis.

	Black soil.	Goradu (Lighter soil).	Sabarmati Alluvial.
	Per cent.	Per cent.	Per cent.
Loss on ignition	6.74	4.06	2.90
Sand and Insoluble silicates	69.66	80.58	92.78
Lime	4.20	2.64	0.73
Magnesia	0.30	0.50	....
Potash	0.56	0.50	0.87
Phosphoric acid	0.16	0.17	0.08
Nitrogen	0.09	0.06	0.07

TABLE NO. 32.
Mechanical Analysis.

	Per cent.	Per cent.
Clay and finest silt	15.22	11.47
Fine silt	8.95	7.44
Medium silt	12.18	8.34
Coarse silt	24.10	10.52
Fine sand	36.18	31.65
Coarse sand	3.37	30.58

The above figures bring out clearly the difference between the black and the lighter soils. The black soil is a loam. The lighter soil is sandy loam and is less retentive than the black as shown by the loss on ignition and the high proportion of fine and coarse sand. It also contains less of lime but both of them are quite good in plant food constituents.

The Sabarmati alluvial which is the richest in yielding crops in the Ahmedabad district is not as rich as the other two soils in lime and phosphoric acid. Its superiority over others must be due to the materials being easily available to the plants. This kind of light soil differs much from the light soils found on the trap and other hard rocks. There the light soils are half disintegrated rock forming a shallow layer while the soil of the Sabarmati alluvial contains well disintegrated material and the soils are deep so that the plants can spread their roots deep and draw fully on the vast stores of plant foods present.

Sandy loam has but a small retentive power for moisture while the black soil retains a high percentage. The percentages for loss on ignition, nitrogen and sand indicate the differences in the three soils. As the insoluble silica and silicates decrease the loss on ignition and nitrogen increase, The soils are quite good in potash and phosphoric acid and fair in lime and nitrogen.

The mechanical analyses of the sandy and medium black soils are given in the table below :—

TABLE No. 30.

	Sandy.	Medium Black.
	Per cent.	Per cent.
Clay and finest silt	6.73	9.75
Fine silt	3.54	3.54
Medium silt	5.13	5.32
Coarse silt	9.77	8.92
Fine sand	67.98	61.21
Coarse sand	6.85	11.26

Even the medium black soil is practically sandy or at best a sandy loam.

(B) Ahmedabad District.

Area.—The district of Ahmedabad lies between 21° 26' and 23° 37' north latitude and 71° 19' and 73° 27' east longitude and covers an area of 3,816 square miles.

Physical features and rainfall.—In the extreme south and also just beyond the northern boundary, are a few rocky hills. But between these points the whole of the district forms a level plain gradually rising towards the north and east. The average rainfall of the district is about twenty-nine inches.

Soils.—There are two chief kinds of soils, the black or *kali* and the light or *goradu*. The black soil is found chiefly towards the west and the light soil in the east. The black has a subsoil of modular and stone and gravel. It is many times impregnated with salts. The light soils are well supplied with springs, which, after the early harvest has been reaped, enable the cultivators at very little cost to have cold weather, *rabi* and even hot weather crops. With the help of manure and water the light soil is very fertile. During dry weather it wears into a loose fine sand but when the rain falls it becomes tolerably compact. Two other varieties of soil deserve mention—an alluvial deposit of the Sabarmati river and a red stony soil. The alluvial deposit of the Sabarmati is the most fertile soil in the district, easily irrigated, holding water at the depth of a few feet below the surface. The stony soil good for growing maize is found in the north-east sub-division of Prantij.

The following figures bring out the differences in the different classes of soils of the Ahmedabad District. We shall first take typical individual soils and then have the variation as shown by each class with regard to chemical and mechanical analyses :—

TABLE NO. 31.
Chemical Analysis.

	• •		
	Black soil.	Goradu (Lighter soil).	Sabarmati Alluvial.
	Per cent.	Per cent.	Per cent.
Loss on ignition	6.74	4.06	2.90
Sand and Insoluble silicates	69.66	80.58	92.78
Lime	4.20	2.64	0.73
Magnesia	0.30	0.50	....
Potash	0.56	0.50	0.67
Phosphoric acid	0.16	0.17	0.08
Nitrogen	0.09	0.06	0.07

TABLE NO. 32.
Mechanical Analysis.

	Per cent.	Per cent.
Clay and finest silt	15.22	11.47
Fine silt	8.95	7.44
Medium silt	12.18	8.34
Coarse silt	24.10	10.52
Fine sand	36.18	31.65
Coarse sand	3.37	30.58

The above figures bring out clearly the difference between the black and the lighter soils. The black soil is a loam. The lighter soil is sandy loam and is less retentive than the black as shown by the loss on ignition and the high proportion of fine and coarse sand. It also contains less of lime but both of them are quite good in plant food constituents.

The Sabarmati alluvial which is the richest in yielding crops in the Ahmedabad district is not as rich as the other two soils in lime and phosphoric acid. Its superiority over others must be due to the materials being easily available to the plants. This kind of light soil differs much from the light soils found on the trap and other hard rocks. There the light soils are half disintegrated rock forming a shallow layer while the soil of the Sabarmati alluvial contains well disintegrated material and the soils are deep so that the plants can spread their roots deep and draw fully on the vast stores of plant foods present.

The subsoils under the black and the lighter soils resemble the soils under which they lie. Their figures of chemical and mechanical analysis are given in the following tables:—

TABLE NO. 33.
Chemical Analysis.

	Sub-soil under black soil.	Sub-soil under Goradu lighter soil.
	Per cent.	Per cent.
Loss on ignition	5.90	3.60
Sand and insoluble silicates	73.64	81.50
Lime	3.76	3.08
Magnesia	0.30	0.50
Potash	0.43	0.48
Phosphoric acid	0.13	0.12
Nitrogen	0.097	0.043

TABLE NO. 34.
Mechanical Analysis.

	Per cent.	Per cent.
Clay and finest silt	12.28	12.96
Fine silt	6.80	8.77
Medium silt	8.91	9.42
Coarse silt	18.54	8.80
Fine sand	47.98	27.34
Coarse sand	5.46	32.71

The soils are very deep and of the same nature to a great depth. That is the reason why these soils are rich in yielding crops.

The following table gives the variation in the constituents of a large number of soils from the Ahmedabad district:—

TABLE NO. 35.
Chemical Analysis.

	Black soils.	Goradu soils.	Sabarmati deposits.
	Per cent.	Per cent.	Per cent.
Loss on ignition	4.84 to 6.74	3.60 to 4.06	2.22 to 2.90
Sand and insoluble silicates	67.44 to 74.88	72.04 to 82.82	83.96 to 95.08
Lime	1.84 to 4.98	2.1 to 4.0	0.50 to 0.73
Potash	0.40 to 0.56	0.48 to 0.68	0.29 to 0.67
Phosphoric acid	0.08 to 0.16	0.12 to 0.17	0.03 to 0.09
Nitrogen	0.05 to 0.09	0.04 to 0.09	0.03 to 0.07

The three types of soils show their distinctive characteristics in the above figures for loss on ignition and sand and insoluble silicates. The Sabarmati soils are low in lime but in other respects the three types show very similar variation in their plant food constituents.

(C) Kaira District.

Area.—The district of Kaira lies between 22° 14' and 23° 7' north latitude and 72° 30' and 73° 23' east longitude and occupies an area of 1,608 square miles.

Physical features and rainfall.—Kaira is a lowland country situated between the rivers Sabarmati and Mahi. The land in the centre is a tract of the most fertile soil. Besides the two large rivers, the country is watered by several small streams. The rainfall of the district is about 34 inches.

Soils.—The soils of the district are of four chief kinds, light or *gorat*, medium or *besar*, black or *kali* and alluvial or *bhatha*. The light or *gorat* is the prevailing soil varying from loose-grained yellow sand of the fields near the Sabarmati and the Mahi to a rich light brown found in central talukas and in the south-west corner of Matar. The rich variety is known as *goradu besar*. Under medium or *besar* are several soils varying from heavy sands to light clays. Soils of this class are distributed all over the district but nowhere are they found over large areas. As a rule the black or *kali* soil is poor, and scarcely ever deep. Alluvial soil or *bhatha* is chiefly found near the Vatrak river.

As indicated above the prevailing soil of the district is the light or *gorat* soil. Chemical analysis of this type of soil is as follows:—

TABLE NO. 36.

			Per cent.
Loss on ignition	..	..	4.6
Sand	..	..	79.4
Lime	..	..	3.77
Phosphoric acid	..	..	0.15
Nitrogen	..	..	0.056

Mechanical analysis of the same is:—

TABLE NO. 37.

			Per cent.
Clay and finest silt	..	..	10.64
Fine silt	..	..	5.44
Medium silt	..	..	5.81
Coarse silt	..	..	24.79
Fine sand	..	..	52.96
Coarse sand	..	..	0.36

This is distinctly a sandy soil rich in plant food constituents. A large number of samples examined show that there are two types of soils—one finer and the other coarser. All the soils are fairly rich in plant food constituents and are well drained. The following table will give the variations met with in the two types:—

TABLE NO. 38.

Chemical Analysis.

	Finer.		Coarser.	
	Per cent.		Per cent.	
Loss on ignition	3.58	to 5.02	1.94	to 2.18
Silica and insoluble silicates	79.4	to 85.4	89.5	to 92.4
Lime	2.41	to 3.77	0.50	to 1.26
Phosphoric acid	0.14	to 0.18	0.08	to 0.18
Nitrogen	0.046	to 0.081	0.036	to 0.044

TABLE NO. 39.

Mechanical Analysis.

	Finer.		Coarser.	
	Per cent.		Per cent.	
Clay and finest silt	10.14	to 13.55	5.93	to 9.90
Fine silt	3.17	to 5.44	1.28	to 3.53
Medium silt	3.57	to 5.81	0.94	to 2.16
Coarse silt	14.07	to 24.79	5.00	to 17.55
Fine sand	62.96	to 64.74	66.07	to 83.75
Coarse sand	0.36	to 0.89	2.67	to 18.22

(D) Broach District.

Area.—The district of Broach lies between 21° 25' and 22° 15' north latitude and 72° 31' and 73° 10' East longitude and covers an area of 1,467 square miles.

Physical features and rainfall.—The district forms an alluvial plain fifty-four miles in length, sloping gently westwards to the shores. Except a few hillocks of sand-drift on the coast the level of the plain is practically unbroken. The temperature varies from 46° F. in December to 112° F. in May. The annual rainfall is slightly over 33 inches.

Soils.—The soils of the district are divided into black and light with several sub-divisions. The different varieties of black soil occupy about three-fourths of the whole cultivable area. They range from the rich alluvial deposits on the banks of the Narbada, through the regular deep cotton soil to the shallow lands near the sea. Staple crops on the black soil are rice, cotton, wheat, *jowar* and *bajri*. In the seaside country of Vagra, Jambusar and Amod the conditions are similar to those of

Ahmedabad tract. The light soil *gorat*, *goradu* varies from the consolidated sand-drift in the south of the district, to the heavier lards merging into rich alluvial soil of *bhatha*. *Gorat* occupies in the north nearly one-third of Jambusar Taluka. It yields *lajri*, *jouari*, pulses and garden crops. *Bhatha* is a rich alluvial deposit and raises all kinds of products, especially tobacco and castor oil plants.

In the table below are given the analytical figures of typical soils. These indicate the nature of the three soils.

TABLE NO. 40.
Chemical Analysis.

	Black cotton Soil.		Bhata Soil.		Gorat Soil.	
	Surface Soil.	Subsoil.	Surface Soil.	Subsoil.	Surface Soil.	Subsoil.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Moisture	6.40	6.44	2.56	3.42	4.20	3.84
Organic matter	7.60	7.78	5.68	4.84	4.20	5.04
Sand	60.72	61.96	73.46	73.62	68.94	70.24
Lime as CaO	0.398	0.734	0.286	0.286	0.398	0.342
Magnesia as MgO	0.90	1.30	0.50	0.80	0.60	0.60
Potash as K ₂ O	0.077	0.116	0.115	0.212	0.097	0.193
Phosphoric acid as P ₂ O ₅	0.074	0.133	0.085	0.093	0.085	0.070
Nitrogen	0.051	0.054	0.078	0.07	0.038	0.024

TABLE NO. 41.
Mechanical Analysis.

	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Clay and finest silt	44.36	52.63	17.43	15.97	14.93	34.33
Fine silt	8.08	7.12	3.87	4.02	3.28	2.58
Medium silt	11.84	9.68	8.96	8.10	5.88	5.09
Coarse silt	14.65	11.17	24.07	22.49	11.47	12.05
Fine sand	20.70	18.35	39.16	44.33	63.85	64.92
Coarse sand	0.37	1.05	6.51	5.09	0.67	1.03

In the chemical analysis the least amount of sand is shown by the black cotton soil and the highest by the *bhatha* soil. They all contain nearly the same percentage of lime which is small. They are all quite good in potash and in phosphoric acid. In nitrogen the *bhatha* soil though not rich is the best of the three while the *gorat* is poor.

The mechanical analysis gives very high figures of clay and finest silt for black cotton soil while for the other soils these constituents are comparatively low, though they are enough to allow the soils to be sufficiently retentive of water. In *gorat* the fine sand goes up to 64 per cent. while in the black cotton soil it is about 50 per cent. The following table gives the percentage of constituents which hold down water and which allow it to pass.

TABLE No. 42.

	Black cotton soil.	Bhatha soil.	Gerat soil.
	Per cent.	Per cent.	Per cent.
Constituents which tend to retain water ..	64·28	30·26	24·01
Constituents which allow water to pass ..	35·72	69·74	75·99

These soils are distinct types. The soils and the subsoils do not differ from each other in their chemical or mechanical analyses. The large number of soils examined show but very little variation in the analytical figures of these typical soils. It is only the lime which goes up to 3 per cent. in some samples, is a varying constituent.

(E) Surat District.

Area.—Surat district lies between 20° 17' and 21° 28' North latitude and 72° 35' and 73° 29' East longitude and covers an area of 1,653 square miles.

Physical features and rainfall.—The district forms an alluvial plain stretching from north to south for about eighty miles, and with a gradual slope from east to west. The district can be divided into three belts running from north to south, parallel to the line of the coast. Nearest the sea is a barren stretch of sand drift and salt marsh, behind that a richly cultivated plain, and further east a poorer and more open land rising gradually into a hilly tract. The rainfall is the heaviest in the southern talukas where it averages 66 inches. In the rest of the district the average for the coast is about 40 inches while inland it is 53 inches.

Soils.—The soils of the district, all more or less alluvial in character, belong to three classes: The black soil, the light *gorat* soil and the third which unites the characteristics of the other two.

Typical samples of black cotton soils give the following figures for three localities in Surat District:—

TABLE No. 43.

	Surat Taluka.		Bulsar Taluka.		Olpad Taluka.	
	Soil.	Subsoil.	Soil.	Subsoil.	Soil.	Subsoil.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Moisture ..	4·90	4·98	5·46	5·92	7·86	7·78
Loss on ignition ..	3·90	6·18	7·90	7·50	7·34	7·44
Sand ..	60·20	75·36	68·16	68·36	70·18	66·92
Lime ..	0·75	0·41	1·05	0·60	0·79	0·96
Potash ..	0·29	0·33	0·21	0·25	..	..
Phosphoric acid ..	0·073	0·10	0·04	0·03	0·06	0·06
Nitrogen ..	0·04	0·035	0·068	0·044	0·04	0·04

These represent the generality of black cotton soil in the Surat District. They differ but slightly from each other. Some samples contain lime much higher than in the above samples and exceptionally the percentage may be found to go up to 5 or 6 per cent. These soils are quite good in potash and fair in phosphoric acid and nitrogen. The soils and subsoils do not differ much from each other in the proportion of the important constituents. The figures for the mechanical analysis of the same soils are as follows :—

•TABLE NO. 44.

	Surat Taluka.		Bulsar Taluka.		Olpad Taluka.	
	Soil.	Subsoil.	Soil.	Subsoil.	Soil.	Subsoil.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Clay and finest silt ..	32·29	28·27	36·58	48·19	37·52	39·04
Fine silt ..	6·36	7·79	10·50	10·20	8·06	13·06
Medium silt ..	7·39	7·44	5·59	6·98	6·97	6·98
Coarse silt ..	27·42	29·22	22·62	17·32	16·91	17·77
Fine sand ..	26·34	26·58	21·29	14·88	29·80	22·78
Coarse sand ..	0·20	0·10	3·42	2·43	0·74	0·37

The soils of Bulsar and Olpad are slightly more clayey than the soils of Surat but on the whole they are similar and contain nearly an equal proportion of constituents which increase retentivity in the soil and of those which decrease retentivity in the soil. Taking the three typical soils we get the following proportions :—

TABLE NO. 45.

	Surat Taluka. Soil.	Bulsar Taluka. Soil.	Olpad Taluka. Soil.
	Per cent.	Per cent.	Per cent.
Constituents which increase retentivity ..	46·04	52·67	52·55
Constituents which decrease retentivity ..	53·96	47·33	47·45

Typical *Gorat* soils show the following percentages of chemical constituents :—

TABLE NO. 46.

	I Per cent.	II Per cent.
Moisture ..	3·46	3·50
Loss on ignition..	6·18	6·38
Sand ..	72·10	73·32
Lime ..	0·51	0·24
Potash ..	0·25	0·33
Phosphoric acid..	0·03	0·07
Nitrogen ..	0·08	0·09

Compared to the black cotton soils of the district the *gorat* contains a large proportion of sand and insoluble matter and a low percentage of lime. In other constituents the *gorat* does not differ from the black cotton soil. The proportions of the physical constituents are as follows :—

TABLE NO. 47.

	I	II	
	Per cent.	Per cent.	
Clay and finest silt .	6.51	6.81	} 21.23 Constituents which increase retentivity.
Fine silt ..	6.92	6.40	
Medium silt ..	7.86	8.02	
Fine sand ..	19.80	21.10	} 78.77 Constituents which decrease retentivity.
Medium sand ..	52.26	49.76	
Coarse sand ..	6.65	7.91	

Although these soils are well drained yet they contain enough of clay and fine matter to retain sufficient water for crops. Such a soil with fairly good proportions of plant food constituents as shown by the chemical analysis are very good for irrigated and garden crops and some of the best garden crops of Surat District are grown on this kind of soil.

As stated before, besides the two distinct soils, there are others which unite the characteristics of the two. In the proportion of chemical constituents there is very little difference between the two soils on one hand and the intermediate soils on the other except in lime which is intermediate. This will be seen from the samples given below :—

TABLE NO. 48.

	Per cent.
Moisture ..	5.73
Loss on ignition ..	6.50
Lime ..	0.99
Potash ..	0.174
Phosphoric acid ..	0.065
Nitrogen ..	0.044

In the proportion of mechanical constituents however the intermediate soils are intermediate between the black cotton and the *gorat* soil :—

TABLE NO. 49.

	Per cent.	Per cent.	
Clay and finest silt ..	21.80	} 38.48	Constituents which increase retentivity.
Fine silt ..	12.16		
Medium silt ..	4.52		
Fine sand ..	24.91	} 61.52	Constituents which decrease retentivity.
Medium sand ..	35.55		
Coarse sand ..	1.06		

Putting the mechanical constituents side by side the difference is brought out clearly.

TABLE NO. 50.

	Constituents which increase retentivity.		Constituents which decrease retentivity.	
	Per cent.		Per cent.	
Black cotton soils	52·67	47·33		
Intermediate soils	33·48	61·52		
Gorai soils	21·23	78·77		

The study of the analysis of the various soils in the Surat District brings out clearly that the different characteristics exhibited by these soils are due not quite so much to the differences in the proportions of their chemical constituents but to the differences in the proportions of their mechanical constituents.

CHAPTER IV.

SOILS OF THE DECCAN DISTRICTS.

The Deccan Districts include East Khandesh and West Khandesh forming one group and the remaining five districts—Nasik, Ahmednagar, Poona, Satara and Sholapur—forming the second group. All the districts have got only one kind of rock underlying, namely, the Deccan Trap. The soils, however, show a good deal of variation as can be seen from the details which follow.

(A) East Khandesh.

Area.—The district of East Khandesh lies between 20° 16' and 21° 27' North latitude and 76° 52' and 76° 24' East longitude and covers an area of 4,424 square miles.

Physical features and rainfall.—East Khandesh abuts on the Deccan upland and includes on its northern frontier an extensive tract of high hills belonging to the Satpuras. It is intersected by the Tapti River and drained by it and also by the Girna and the Purna. The average rainfall of the district is about 28 inches.

Rocks.—The prevailing rock is the Deccan trap with its different varieties.

Soils.—The banks of the Tapti form very extensive plains of the richest soil. The Tapti valley, is on the north well-wooded and on the south, except in the Bhusaval Taluka, grows many mango trees. The Girna valley is fringed with poor red soil and waste lands which are rugged and stoney. The soil near the river banks is better, though much inferior to the Tapti valley soils. The black soils of East and West Khandesh have a common origin and in their composition they resemble each other very much. The following table gives analysis of a typical cotton black soil and the subsoil underneath it and one light soil.

TABLE NO. 51.
Chemical Analysis.

	Black Soil.	Black Subsoil.	Light Soil.
	Per cent.	Per cent.	Per cent.
Loss on ignition	9.20	10.0	..
Sand and insoluble silicates	60.14	64.34	79.34
Lime	2.69	4.20	..
Magnesia	0.20	0.40	..
Potash	0.20	0.60	0.29
Phosphoric acid	0.09	0.10	0.10
Nitrogen	0.11	0.058	0.04

TABLE NO. 52.
Mechanical Analysis.

Clay and finest silt	49.15	51.04
Fine silt	3.99	5.63
Medium silt	6.34	7.46
Coarse silt	10.76	9.87
Fine sand	25.62	24.47
Coarse sand	4.15	1.53

Variation in the figures from a large number of black soil samples are given in the following table :—

TABLE NO. 53.
Chemical Analysis.

	Per cent.
Loss on ignition	9.20 to 20.00
Sand and insoluble silicates	63.16 to 68.36
Lime	1.12 to 4.48
Potash	0.17 to 0.73
Phosphoric acid	0.08 to 0.16
Nitrogen	0.04 to 0.11

The striking feature of all the Khandesh soils is that they are well provided with plant food constituents and their mechanical condition is quite good, for cotton and rabi crops of wheat, etc. They have all been derived from trap and have been brought and deposited on the banks of the rivers by their waters.

(B) West Khandesh.

Area.—The district of West Khandesh lies between 20° 38' and 22° 2' North latitude and 73° 35' and 75° 17' East longitude and covers an area of 5,439 square miles.

Physical features and rainfall.—West Khandesh is hilly and rugged except where wide black soil plains extend on either side of the Tapti and its tributaries. The Tapti plain of Shirpur is rich but the northern parts are hilly. The average rainfall of West Khandesh is 24 inches.

Rocks.—The prevailing rocks of the district are the Deccan trap and its varieties.

Soils.—The soils of this district are essentially derived from Trap. Along the banks of the Tapti river and its tributaries there are deep black cotton soils. They are very deep and retentive but away from the rivers and near the hills the soils are shallow and of lighter type. The following figures show the composition of two typical black cotton soils and one subsoil of West Khandesh :—

TABLE No. 54.

Chemical Analysis.

	Black cotton soil I.	Black cotton soil II.	Subsoil under No. III.
	Per cent.	Per cent.	Per cent.
Loss on ignition	11·66	9·16	9·18
Sand and insoluble silicates	55·70	64·00	62·64
Lime	4·39	1·63	1·13
Magnesia	5·27	0·50	0·50
Potash	0·53	0·17	0·40
Phosphoric acid	0·10	0·08	0·07
Nitrogen	0·054	0·11	0·064

TABLE No. 55.

Mechanical Analysis.

	Black cotton soil I	Black cotton soil II.	Subsoil under No. III.
	Per cent.	Per cent.	Per cent.
Clay and finest silt	42·84	45·46	47·12
Fine silt	8·65	4·56	4·68
Medium silt	18·63	6·15	6·40
Coarse silt	13·53	12·84	12·14
Fine sand	14·13	26·52	25·68
Coarse sand and gravel	4·13	4·47	4·08

All the three soils very closely resemble each other except in the case of lime and magnesia which may vary from place to place. On the whole the soils are well stocked with plant food constituents. The soils are

sufficiently retentive of moisture for a crop like the cotton and also contain enough of coarser particles to keep the soil in a good physical condition.

(C) Nasik District.

Area.—The district of Nasik lies between $19^{\circ} 35'$ and $20^{\circ} 53'$ north latitude and $73^{\circ} 15'$ and $74^{\circ} 56'$ east longitude and covers an area of 5,892 square miles.

Physical features and Natural divisions and rainfall.—With the exception of a few villages in the west the whole district is situated on a table-land. The table-land portion is divided into three tracts (1) *Dangs*, (2) *Desh* and (3) Transition. The general characteristic of the *Dangs* is rough, hilly ground. It stretches east from the crest of the Sahyadries and varies from ten to thirty miles in width. The rainfall is generally high. The *Desh* includes Malegaon, Nandgaon, Yeola Niphad and the eastern portions of Chandor and Sinnar talukas with rainfall from 18 to 28 inches. The transition tract includes the rest of Sinnar and Chandor and parts of Baglan, Kalwan Dindori and Nasik talukas. This tract has a rainfall varying from 30 to 40 inches.

Rocks.—The whole district forms part of what is known as the trap region of the Deccan.

The trap includes compact stratified basalts and also softer amygdaloidal trap. A peculiar feature in the geology of the district is the absence of the laterite, which is found capping the hills in the southern districts. There is no tract of laterite of any large extent though there appear to be slight traces of it at the Thal pass through which the Great Indian Peninsula Railway enters Igatpuri. The lithological character of the basalt varies greatly. In some cases the tabular trap is of fine texture, and takes a fair polish, in others it is coarse and nodular.

Soils.—There are four kinds of soils:—(1) black or *kali* (2) red *mal* (3) reddish black which is a mixture of red and black and (4) light brown called *barad*. Except in the uplands, where some of it is poor, black soil as found mostly in the plain country near the beds of rivers, is often deep, and very rich and yield excellent cold weather crops of wheat and gram. Red soil which is stiffer and shallower is found chiefly on hill slopes or plateaus and yields good rainy season crops. The reddish black coloured soil which is a mixture of the red and the black is found occasionally in hilly tracts, and yields gram, lentils, and other cold weather crops. Light brown which is found on hilly lands is often strewn with boulders and mixed with lime nodules. It never gives more than a light crop and yields nothing at all when the rainfall is scanty.

Black soils.—Twenty-six samples of black soils from the transition tract and five samples from *Desh* tract were analysed. The samples from the *Desh* tract were analysed only for nitrogen, potash and phosphoric acid.

The variations are given below :—

TABLE NO. 56.

Chemical Analysis.

	Transition tract.	Desh tract.
	Per cent.	Per cent.
Loss on ignition	14·34 to 20·92	
Silica and insoluble silicates	52·56 to 65·76	
Lime	3·36 to 7·84	
Potash	0·42 to 0·85	0·53 to 0·90
Phosphoric acid	0·15 to 0·57	0·073 to 0·23
Nitrogen	0·05 to 1·0	0·06 to 0·14

Chemical analysis shows that these black soils are well provided with the necessary plant food constituents. They are rich in lime. The loss on ignition shows that they have a good retentive capacity for water and for manurial ingredients. The physical analysis given below shows that the various separates are in good proportion with regard to water-holding capacity and also keeping the soil with good drainage. This is the reason why with good rainfall or with irrigation facilities the soils yield good grain crops and also grow good crops of vegetables and such crops as the grapes.

TABLE NO. 57.

Mechanical Analysis.

	Per cent.
Clays, finest silt and fine silt	14·50 to 20·56
Medium silt	4·31 to 9·55
Coarse silt	10·72 to 15·15
Fine sand	29·71 to 35·32
Coarse sand	24·03 to 33·09

Some lands in the Malegaon Taluka—desh tract—were left as waste without cultivation for over twenty-five years and the black soils from this place give comparatively lower figures for the plant food constituents. The potash was found to be about 0·06 per cent. and phosphoric acid about 0·03 to 0·04 per cent. and even lime though enough in quantity is less than in the soils given above.

Reddish black and Red soils.—These are inferior in every way to the black soils and out of the reddish black and red, the latter are poorer than the former. The analytical figures are as follows :—

TABLE NO. 58.

Chemical Analysis.

	Reddish black soils.	Red soils.
	Per cent.	Per cent.
Loss on ignition	8.90 to 9.40	5.90 to 8.10
Silica and insoluble silicates	45.0 to 56.0	70.90 to 75.0
Lime	9.70 to 10.20	1.12 to 1.73
Potash	0.10 to 0.16	0.06 to 0.10
Phosphoric acid	0.04 to 0.50	0.02 to 0.04
Nitrogen	0.09 to 0.11	0.06 to 0.09

The figures for loss on ignition and sand show that the reddish black soils, though not quite so good in their retentive power as the black soils are good enough to grow crops with a sufficient supply of water. The red soils, however, are not much retentive and tend to be hungry. In the plant food constituents the reddish black soils are good enough but the red soils are comparatively poor and hence the red soils give some crops only when there is sufficient water but otherwise practically very little is expected out of them.

There are some soils which are poor in yielding crops. They are white coloured, exceedingly dry and hungry and yield if at all a poor crop.

Their analytical figures are as follows :—

TABLE NO. 59.

Chemical Analysis.

	Per cent.
Loss on ignition	3.00 to 5.40
Silica and insoluble silicates	75.20 to 80.40
Lime	2.90 to 3.10
Potash	0.10 to 0.15
Phosphoric acid	0.07 to 0.07
Nitrogen	0.02 to 0.03

Lime, potash and phosphoric acid are not deficient but the poverty and the hungry character of the soils are shown by the high percentage of sand and a low percentage of loss on ignition. The last indicates that the soil has very little water-holding capacity and unless there is a good amount of water there will be no good crop.

(D) Ahmednagar District.

Area.—The district of Ahmednagar lies between 18° 20' and 19° 59' north latitude and 73° 37' and 75° 41' east longitude and occupies an area of 6,629 square miles.

Physical features and rainfall.—The principal geographical feature of the district is the chain of the western Ghats which extends along a small portion of the western boundary and throws out three great spurs and ridges towards the east. These spurs continue to run eastwards into the heart of the district, the valleys between them forming the beds of the Pravara and the Mula rivers. The district also has two parts—the *Dang* or hilly country and the *Desh* or plain country. But the *Dangs* here are only a small part, occupying western half of the Akola taluka. In the Godavari valley are the fertile alluvial plains of Kopergaon, Rahuri, Nevasa and Shevgaon, growing wheat, millets, cotton and oil seeds. In the south lie the alluvial, though less fertile, tracts of Shrigonda and Karjat in the Bhima valley. Between these valleys there is every variety of bare hill and cultivated dale in the Sangamner, Parner and Nagar talukas and Jamkhed mahal. The rainfall in the *Dangs* is 200 inches but the average rainfall of *Desh* which forms almost the whole of the district is only 20 inches.

Rocks.—The whole district forms part of the great trap region of the Deccan. Throughout Ahmednagar the alternate beds of basalt and amygdaloid preserve a striking parallelism to each other. In the basalt prismatic formation is marked in many places. Round or oval masses of compact basalt with concentric layers, known as concretionary or nodular basalt are widely diffused. Vertical basaltic dykes are also met with here and there. Another distinctive feature is the occurrence of strata of red bole rock under-lying thick strata of basalt or amygdaloid. It varies from friable clay to compact earthy jasper. There is also the occurrence of large quantities of loose stones of all sizes. In some places they cover fields several acres in extent, so thickly that the black soil underneath is not seen. There are limestone outcrops at several places on the west side of Kanhur plateau. There are lime stone cliffs worn by water.

Soils.—The three chief kinds of soils in the district are black, red and grey or whitish. The soils along the river banks are deep and rich and gradually grow poorer as they approach the hills. The chemical and mechanical analyses of the various soils show that they do not differ in any way from the typical trap soils of such districts as Poona, Satara or Nasik.

TABLE NO. 60.
Chemical Analysis.

	Deep black.	Medium black.	Limy.
	Per cent.	Per cent.	Per cent.
Loss on ignition	12·30 to 17·20	11·52 to 13·02	17·86
Sand and insoluble silicates	51·70 to 55·20	66·92 to 72·52	22·60
Lime	6·44 to 8·84	1·46 to 5·60	17·41
Potash	0·40 to 1·20	0·23 to 0·47	0·65
Phosphoric acid	0·17 to 0·39	0·11 to 1·23	0·14
Nitrogen	0·04 to 0·15	0·05 to 0·06	0·07

TABLE NO. 61.

Mechanical Analysis.

	A typical black soil.		Lighter soils.
	Per cent.		Per cent.
Clay and finest silt, and fine silt	46.57	4.37 to 9.31	
Medium silt	13.89	2.27 to 5.10	
Coarse silt	4.46	7.37 to 10.76	
Fine sand	20.68	69.37 to 82.93	
Coarse sand	14.40	3.66 to 5.88	

The soils are rich in plant food constituents and the black soils are retentive of moisture. With a good supply of water these should and do give excellent crops.

(E) Poona District.

Area.—The district of Poona lies between 17° 54' and 19° 24' north latitude and 70° 19' and 75° 10' east longitude and covers an area of 5,357 square miles.

Physical features.—Towards the west the country is undulating and intersected by numerous spurs of the Western Ghats. To the east of the rugged hilly western belt is the Transition belt and to the east of this is the *Desh* tract. The *Desh* tract is a plain country.

Climate and rainfall.—On the western side the rainfall is heavy and goes up to 200 inches on some crests. In the transition tract the average rainfall is 30 inches while in the *Desh* tract it is 20 inches.

Rocks.—The prevalent rock of the Poona District is all trap. Practically all the varieties of trap such as the concretionary, vesicular, amygdaloidal tract, etc., and also black, brown and reddish coloured trap are found in the district.

Soils.—The soils of the district are lighter in the west than in the east. They belong to three classes, black or medium black (*kali*), red (*tambadi*) and coarse grey (*barad*). In many places each kind of soil mixes with the other in various proportions and in turn is modified by sand, gravel, lime and other ingredients. In the study of the soils of the Poona district it will be convenient if they are considered separately according to the tract from which they come. As has already been mentioned above there are three separate tracts of which the Poona district is composed and each of these should be dealt with separately. The three tracts are (1) the *mawal* tract, (2) the Transition tract and (3) the *Desh* tract.

The mawal tract.—It is mostly the western part of the district extending right from the north of Junnar Taluka down to the southernmost part of the Bhor State where it touches the Kolaba district. In

fact it is a belt of the topmost hills of the Sahyadri mountains. The hilly belt comprises about a third of Junnar, Khed and Haveli Talukas and half of Purandar Taluka and Bhor State.

The South west monsoons break up on the hills of the western Ghats and heavy downpours of rain are received by the *maual* tract during the months of June to September. Although the tract receives so much rain very little of it is retained. Most of it runs down the slopes carrying with it fine particles of soil. The soils on the hill slopes are poor and shallow and grow only inferior millets. The soils at the foot of the slopes are good enough to grow rice and with a good amount of late rains a second crop of *wal*. Some of the best rice in the Presidency is grown in this tract.

TABLE NO. 62.

Chemical analysis of Typical Nachani and Rice Soils.

	Nachani soils		Rice soils.	
	Minimum.	Maximum.	Minimum.	Maximum.
	Per cent.	Per cent.	Per cent.	Per cent.
Loss on ignition	4.98	7.91	7.29	8.17
Silica and Insoluble silicates	62.58	71.27	59.23	61.99
Iron and Alumina	16.28	20.28	20.98	23.58
Lime	0.74	0.78	0.69	1.06
Magnesia	0.66	1.12	0.94	1.22
Potash	0.08	0.15	0.09	0.11
Phosphoric acid	0.08	0.09	0.051	0.076
Nitrogen	0.07	0.07	0.052	0.126

The *nachani* soils are from the higher portion of the hill and are shallow while the rice soils are from the valley portion but they do not show much difference in the proportion of total plant food constituents. They, however, differ in their mechanical analysis as shown by the following two typical soils :—

TABLE NO. 63.

	Nachani soil.	Rice soil.
	Per cent.	Per cent.
Clay and finest silt	16.31	26.53
Fine silt	4.45	8.49
Medium silt	5.01	6.35
Coarse silt	18.73	17.17
Fine sand	38.43	25.18
Coarse sand	17.07	16.28

The rice soils are more clayey and have more retentive power than the *nachani* soils. But the chief difference is that the *nachani* soils are shallow while the rice soils are comparatively deep.

The transition tract.—This tract lies between the hilly heavy rainfall tract on the western side and the plain dry *Desh* tract on the eastern side. The transition strip extends right from the northernmost part of Junnar Taluka to the southernmost of Haveli. It includes a large part of Junnar, Khed and Haveli Talukas and part of Purandhar Taluka. As the tract is situated at the foot of the hill slopes, it has two advantages, viz., (1) it receives sufficient rainfall (though at times it may not be enough), and (2) it receives washings from the hills which go to enrich the soils. Many of the soils, therefore, are fertile. The best garden soils of the district are situated in this tract. Sugarcane is extensively grown. Grapes, figs, oranges, plantains, etc., are also grown with success. It is a well-known tract for vegetables. These are cultivated either on canal or well irrigation.

During the village study started by Dr. H. H. Mann all the types of the soils found at Pimla Soudagar* (about six miles from Poona) were analysed. This is a typical village of the transition tract and the soils there represent soils found in the transition tract all over the Bombay Deccan and hence these are given below in detail.

The so-called *murum* is a material produced by the decay of the rock in situ. The *murum* layer is commonly, though not universally, found between the rock and the actual surface soil in the Deccan and is many times exposed at the surface and forms a poor type of soil. The *murum* layer is formed of porous material containing half decayed rock which is usually penetrable by plant roots. It is a poor dry soil from four to six inches deep overlying a subsoil of hard *murum* into which plant roots hardly penetrate. Its colour varies from whitish yellow to whitish black. It generally forms a dry hungry soil. With careful tillage it gives, in a favourable season a fair crop of *bajri* (*Pennisetum typhoideum*), *tur* (*Cajanus indicus*) and *niger* (*Ginzotia abyssinica*). A typical specimen of such soil gave the following figures on analysis.

TABLE No. 64.

	Per cent.
Loss on ignition	8.06
Silica and insoluble silicates	79.96
Organic matter (by direct determination)	0.82
Lime (CaO)	0.80
Potash (K ₂ O)	0.93
Phosphoric acid (P ₂ P ₅)	0.11
Nitrogen	0.05

* "Land and Labour in a Deccan Village" by H. H. Mann, D. L. Sahasrabudhe and others. Bombay University Economics Series No. 1 of 1917.

The soil is poor in humus and hence in nitrogen ; in other respects it is well furnished with plant food. Its physical character is shown by the following figures:—

TABLE No. 65.

			Per cent.
Clay and finest silt	..	..	3·11
Fine silt	..	..	3·07
Medium silt	..	..	4·21
Coarse silt	..	..	11·35
Fine sand	..	..	60·78
Coarse sand and gravel	..	..	17·48

These figures are enough to show the very dry character of the soil. Its excessive dryness seems to prevent the development of organic matter, and so such soils in the Deccan remain half-barren. They have low retentivity and hence their extreme poverty.

Yellow soil.—This soil differs little from the murmad soil and where it lies directly on rock it is drier. Its depth does not usually exceed four to five inches. It produces a poor crop with good rain.

The mechanical analysis of a typical specimen shows the hyngry dry nature of the soil.

TABLE No. 66.

			Per cent.
Clay and finest silt	..	..	2·51
Fine silt	..	..	4·65
Medium silt	..	..	3·42
Coarse silt	..	..	8·11
Fine sand	..	..	50·99
Coarse sand and gravel	..	..	30·32

The following figures show the results of chemical analysis:—

TABLE No. 67.

			Per cent.
Loss on ignition	..	..	7·40
Silica and insoluble silicates	..	..	80·80
Organic matter (direct determination)	..	..	0·97
Lime (CaO)	..	..	0·60
Potash (K_2O)	..	..	1·15
Phosphoric acid (P_2O_5)	..	..	0·20
Nitrogen	..	..	0·03

Black soil.—The greater part of the valley portions of the transition tract is composed of black or medium black soil. This material variously called black cotton soil, or regur, derived from the finer portions of decayed trap rock as carried by water to lower levels, is not by any means always similar. Where the finest material and clay predominate, it forms a very clayey soil contracting enormously when

dry and forming masses as hard as rock and consisting of a slimy jelly-like mass when saturated with water. Where the clay is present in lesser quantity the special characters of the soil are exhibited to a smaller degree but they are not dissimilar in kind. The heavier and more clayey black soils are characteristic of the eastern part of the Deccan, for there the slopes are less steep, the water carrying alluvium has to run a greater distance and hence the materials are of a finer texture. As one proceeds to the west the soils, though black and possessing characters above described in a measure, are less heavy and are usually styled "medium black" soil or "light black" soil according to the amount of clay which they contain. The depth of such a soil may vary from a foot to five or six feet. Where the soil is deep there is very little difference between the soil and sub-soil in texture or in colour. The following figures bring out the characters of black soil which is sufficiently deep and clayey :—

TABLE No. 68.

Mechanical Analysis.

		Soil.	Subsoil.
		(0" to 9")	(9" to 18")
		Per cent.	Per cent.
Clay and finest silt	.. ..	4·8	5·7
Fine silt	.. ..	61·2	59·7
Medium silt	.. ..	10·7	13·6
Coarse silt	.. ..	8·4	7·5
Fine sand	.. ..	8·1	7·7
Coarse sand and gravel	.. ..	6·7	5·8

TABLE No. 69.

Chemical Analysis.

		Soil.	Subsoil.
		(0" to 9" deep)	(9" to 18" deep)
		Per cent.	Per cent.
Loss on ignition	.. ..	19·2	20·6
Silica and insoluble silicates	.. ..	63·8	65·7
Organic matter (direct determination)	.. ..	2·38	....
Lime (CaO)	.. ..	1·90	1·40
Potash (K ₂ O)	.. ..	1·60	0·80
Phosphoric acid (P ₂ O ₅)	.. ..	0·23	0·42
Nitrogen	.. ..	0·06	0·05

These figures are exceedingly striking and illustrate in a very effective manner the characteristics of a large part of the black soil areas of the Deccan. There is a great similarity between the soil and the subsoil. As regards the size of the particles the most prominent feature is the

very small quantity of what can be classed as clay on account of its fineness, in a soil so markedly clayey. It is probable that in a soil like this a very small amount of genuine colloidal clay is capable of giving its character to any soil in which fairly fine particles predominate. In no soils is this character so emphasised as in the Deccan black soil; the fine silt here must be also in a very highly hydrolised and in a semi-colloidal condition, and if this is the case the high percentage of combined water would be understood and also the great retentiveness of the soil for water can be explained.

The high percentage of loss by ignition of the dried soil is also a very characteristic feature of black soil and is due to the presence of much combined water and not to a large quantity of organic matter. The organic matter is usually very small. The origin of the black colour is not fully known in spite of many attempts to discover it*. In part it seems to be due to finely divided magnetic oxide of iron but this is not the only cause. One thing is certain that the colour is not due to any thing but to a minor extent to organic matter and in fact the black soils of the Deccan are remarkably deficient in humus and hence in nitrogen. The deficiency in organic matter and nitrogen is perhaps the most strongly marked feature in the chemical analyses of Deccan soils. They are rich otherwise. The total and available phosphoric acid is not low, though the soils often respond to phosphatic manures. They do not much respond to potash manures. The lime is usually sufficient and many times in excess. The soils which are, as shown above, deficient in organic matter respond very quickly to nitrogenous manures, provided the water in the soil is maintained sufficiently high in amount. The water contents represent the limiting factor in the soils of the Deccan. If the water can be guaranteed, it pays to manure heavily with organic and nitrogenous manures.

A typical medium black soil of Pashan—a village about four miles from Poona—in the transition tract gave the following figures:—

TABLE NO. 70.

Mechanical Analysis.

				Per cent.
Clay and finest silt	..	..	..	17·94
Fine silt	..	..	..	9·09
Medium silt	..	..	..	11·17
Coarse silt	..	..	..	13·75
Fine sand	..	..	..	43·82
Coarse sand and gravel	..	..	..	4·23

*Annett—Mem. Dept. Agric., Ind. Chem. Series Vol. I, No. 9 (1910).

Harrison and Shivan—Mem. Dept. Agric., Ind. Chem. Series Vol. II, No. 5 (1912).

TABLE NO. 71.

Chemical Analysis.

	Per cent.
Moisture	6.60
Loss on ignition	11.40
Silica and insoluble silicates	58.40
Iron oxide (Fe_2O_3)	11.99
Alumina (Al_2O_3)	6.50
Lime (CaO)	4.00
Magnesia (MgO)	1.60
Potash (K_2O)	0.40
Phosphoric acid (P_2O_5)	0.08
Nitrogen	0.05

This is sufficiently retentive and yet porous enough to drain properly and hence quite suitable for garden crops.

Silt which accumulates on the river banks yields good garden crops for various reasons. It contains varying minerals well mixed together and well acted upon by the disintegrating agencies and hence contains generally all the plant food constituents sufficiently available to the crops. The soils formed from the silt have a good retentive power and are also well drained. These characteristics are well brought out by the following analytical figures:—

TABLE NO. 72.

Mechanical Analysis.

	Per cent.
Clay and finest silt	19.81
Fine silt	5.79
Medium silt	4.47
Coarse silt	14.99
Fine sand	53.36
Coarse sand	1.58

TABLE NO. 73.

Chemical Analysis.

	Per cent.
Loss on ignition	9.12
Sand and insoluble silicates	62.51
Iron oxide	10.72
Alumina	10.76
Lime	1.05
Potash	0.174
Phosphoric acid	0.09
Nitrogen	0.086

The variation shown by the analysis of a large number of typical soils of the transition tract is given below :—

Murnud soils—

TABLE No. 74.
Chemical Analysis.

	•	•	Minima.	Maxima.
			Per cent.	Per cent.
Loss on ignition .. .. .	..	..	4.25	10.20
Silica and insoluble silicates .. .. .	..	..	68.12	82.46
Lime .. .. .	..	..	0.16	3.83
Potash .. .. .	..	..	0.52†	0.89
Phosphoric acid .. .. .	..	..	0.13‡	0.39
Nitrogen .. .. .	..	..	0.009	0.05

†In one case it was as low as 0.052.

‡In one case it was 0.056.

TABLE No. 75.
Mechanical Analysis.

	•	•	Minima.	Maxima.
			Per cent.	Per cent.
Clay and finest silt .. .. .	..	..	3.32	6.02
Fine silt .. .. .	..	..	3.05	5.90
Medium silt .. .. .	..	..	2.82	5.92
Coarse silt .. .. .	..	..	9.62	15.57
Fine sand .. .. .	..	..	37.22	48.97
Coarse sand and gravel .. .. .	..	..	26.27	39.61

Medium black soils—

TABLE No. 76.
Chemical Analysis.

	•	•	Minima.	Maxima.
			Per cent.	Per cent.
Loss on ignition .. .. .	..	..	8.88	18.56
Silica and insoluble silicates .. .. .	..	..	48.71	68.46
Lime .. .. .	..	..	2.57	5.10
Potash .. .. .	..	..	0.28	0.78
Phosphoric acid .. .. .	..	..	0.05	0.22
Nitrogen .. .. .	..	..	0.05	0.08

TABLE NO. 77.

*Mechanical Analysis.**Medium Black Soils :—*

	Minima.	Maxima.
	Per cent.	Per cent.
Clay and finest silt	21·12	33·43
Fine silt	6·70	10·33
Medium silt	23·00	28·57
Coarse silt	24·34	39·87
Fine sand	11·28	27·75
Coarse sand and gravel		

The Desh or the dry tract.—This tract occupies the whole of the eastern part of the district. It includes Sirur, Bhimthadi, and Indapur Talukas and a part of Haveli and Purandar Talukas. The country is mostly a plain and the soils in many places are fairly good. Some of the best *jowar* and oil-seeds are grown in this tract. Since the advent of the Mutha and Nira-canals large portions of Bhimthadi and Indapur as also a part of Haveli are brought under irrigation. The canal irrigation has turned some of the soils into salt lands.

This tract has some deep black soils but a comparatively large portion is occupied by light black soils. There are then the Murmad soils and here and there we meet with soils which are red in colour. Some of these soils were studied in detail along with the village study in the Deccan. The village *Jategaon (near Shikarpur, 24 miles from Poona on the Poona-Ahmednagar Road) is a typical village of the dry tract in the Poona District and many of the soils there, are representative of those found all over the dry tract of the Deccan.

The medium black or light black soils.—Under this head may be included all those soils which are more than ten inches deep and which have a more or less black colour. They vary usually from ten or twelve inches to about three feet in depth. Under the soil generally there is a layer of *murum* which is merely half decomposed trap. The material drains freely and so once water sinks below the level of the soil, it is practically lost and irrecoverable for the use of all crops and plants except large trees. These soils are of a lighter and less clayey type than the deeper black soils found in many places of the dry tract. The deep cracking of the black soils in the hot weather is less prominent in these soils. These soils, however, include *rabi* lands and what are called the *gavali* or wheat lands. The soils are capable of growing *bjri* in years of good early rains and *shalu jowar* when the rains are late. Wheat and gram are grown on deeper soils. These soils are quite suitable for growing garden crops if irrigation facilities are

* Land and Labour in a Deccan Village No. 2 by H. H. Mann, N. V. Karitlar, Bombay University Economics Series No. 2.

available. A mechanical and chemical examination of the soil and subsoil from two typical places gave the following figures :—

TABLE NO. 78.
Mechanical Analyses.

	No. 1.		No. 2.	
	Soil.	Subsoil.	Soil.	Subsoil.
	Per cent.	Per cent.	Per cent.	Per cent.
Clay and finest silt	4·6	4·0	6·3	4·6
Fine silt	5·6	5·1	6·8	4·1
Medium silt	3·0	3·0	6·8	4·1
Coarse silt	6·9	8·0	14·1	7·6
Fine sand	75·9	75·4	63·3	74·0
Coarse sand	3·9	4·4	2·6	5·6
Stones	7·1	8·3	13·3	17·5

TABLE NO. 79.
Chemical Analyses.

	No. 1.		No. 2.	
	Soil.	Subsoil.	Soil.	Subsoil.
	Per cent.	Per cent.	Per cent.	Per cent.
Loss on ignition	20·00	18·90	18·50	17·40
Silica and insoluble silicates	54·20	60·30	60·80	70·40
Lime	2·90	3·10	3·10	0·30
Potash	0·66	0·37	0·12	0·40
Phosphoric acid	0·03	0·10	0·05	0·03
Nitrogen	0·05	0·05	0·06	0·08

The figures indicate the close similarity of soils. In both cases the large loss on ignition reveals the presence of much highly hydrated substance and hence of very sticky material in the finer portion of the soil.

The murmad soil.—This soil does not differ in any way from the *murmad* soil of other tracts in the Deccan. It consists of highly porous material derived directly from the decomposition of trap. This class of soil is capable of growing only *kharif* or rain crops of the type of *bajri*. When the rains are scanty, the soils covered with stones are the most valued, as being better able to stand drought than other shallow soils. Many of these lands are ploughed in the hot season and harrowed several times for the *kharif* crop. They are capable, when so prepared, of growing *bajri* mixture with even moderate rain in June and July.

A mechanical and chemical examination of two typical samples gave the following figures :—

TABLE No. 80.

Mechanical Analyses.

—	No. 1.	No. 2.
	Surface soil. 9" deep.	Surface soil. 9" deep.
	Per cent.	Per cent.
Clay and finest silt	9·8	3·5
Fine silt	8·7	3·9
Medium silt	5·8	3·3
Coarse silt	10·2	11·6
Fine sand	41·6	59·0
Coarse sand	23·9	18·8
Stones	10·2	22·9

TABLE No. 81.

Chemical Analyses.

—	No. 1.	No. 2.
	Surface soil 9" deep.	Surface soil 9" deep.
	Per cent.	Per cent.
Loss on ignition	13·20	9·30
Silica and insoluble silicates	62·70	75·40
Lime	1·80	0·40
Potash	0·19	0·50
Phosphoric acid	0·06	0·08
Nitrogen	0·04	0·06

It will be seen from the figures given above that the fine matter in the soils is not sufficiently hydrated to be clayey and hence they are pervious to water. This together with their shallowness, accounts for their unsuitability for *rabi* crops, while when level enough to use as irrigated lands, as they some times are, they are known for their very large consumption of water.

The red coloured soils.—The red coloured soils which are found overlying the trap are shallow with a depth up to nine inches. Such soils are generally situated along elevated rocky areas.

The following figures show the mechanical and chemical characters of such soils :—

TABLE NO. 82.

Mechanical Analysis.

				Soil 9" deep Per cent.
Clay and finest silt	..	..	..	4.0
Fine silt	..	• •	..	3.9
Medium silt	..	..	..	10.1
Coarse silt	..	..	..	3.1
Fine sand	..	..	..	71.3
Coarse sand	..	..	..	7.6
Stones	..	..	..	16.1

TABLE NO. 83.

Chemical Analysis.

				Per cent.
Loss on ignition	..	..	..	11.50
Silica and insoluble silicates	..	..	..	76.10
Lime	..	..	..	0.60
Potash	..	..	..	0.15
Phosphoric acid	..	..	..	0.12
Nitrogen	..	..	..	0.06

The individual soils whose analytical figures are given above give a clear idea with regard to the characters of the different types of soils. The above figures are confirmed by the analysis of a very large number of soils. The following figures are the minima and maxima obtained for 39 samples of light black soils found in the dry tract of the Poona District.

TABLE NO. 84.

	Minima.		Maxima.	
		Per cent.		Per cent.
Loss on ignition	..	8.89	..	18.60
Sand	..	50.28	..	65.44
Lime	..	1.00	..	5.93
Potash	..	0.35	..	0.97
Phosphoric acid	..	0.02	..	0.34
Nitrogen	..	0.02	..	0.08
Organic matter (direct method)	..	0.55	..	1.87

TABLE No. 85.

Mechanical analysis of some of these was done and the minima and the maxima figures obtained are given below :—

—	Minima.	Maxima.
	Per cent.	Per cent.
Clay and finest silt	11·0	17·86
Fine silt	9·24	14·29
Medium silt	14·25	24·35
Coarse silt	3·50	10·33
Fine sand	33·95	50·27
Coarse sand	4·89	7·79

TABLE No. 86.

Mechanical analyses of the murmad soils of the dry tract are as under :—

—	Minima.	Maxima.
	Per cent.	Per cent.
Clay and finest silt	6·77	9·44
Fine silt		
Medium silt	7·09	10·11
Coarse silt	16·19	28·49
Fine sand	42·21	53·54
Coarse sand	9·59	16·98

The various analytical figures given so far illustrate what has always been recognised by those who are dealing with agricultural land in the Deccan, namely that the value of soils depends almost entirely on their retentiveness and their depth. The black soils are the best, not because of any essential richness, but because they retain water better than others. The others are inferior not because they are essentially poor, but because they are porous and water runs through them easily, out of the range of the plant roots. Retentiveness and the depth are therefore the most important points in considering the value of these soils.

(F) Satara District.

Area.—The district of Satara lies between 16° 48' and 18° 11' north latitude and 73° 36' and 74° 58' east longitude and covers an area of 4,910 square miles.

Physical features and natural Divisions.—Like other districts which are bounded on the west by the Sahyadris, Satara may be subdivided into three belts, namely, a moist hilly western and a dry eastern country separated by a transition tract. The hilly west is here called the Dongri or hill country. The east goes by the usual name of *Desh*.

the *Desh* tract of this district is more elevated and hilly and has a poorer soil than in similarly situated portions of other districts. The central or transition belt is a tract of rich, well-watered valleys, nearly parallel to each other. The richness of the soil of the transition tract and its usual facilities for irrigation from wells and running streams enhance its measure of immunity from the effects of prolonged drought.

Climate and rainfall.—According to the height above and distance from the sea the climate varies in different parts of the district. In the eastern parts heat is considerable in the months of April and May but near the hills it is moderate. The average rainfall in the hilly tracts varies from 40 inches at Satara to 250 inches on the crest of the *ghats*. The transition tract enjoys a fall of about thirty inches while the *Desh* tract receives 20 to 25 inches of rainfall.

Rocks.—The whole of the Satara district is situated on the Deccan trap. In the hills trap is capped with layers of laterite. The trap is chiefly amygdaloidal or concretionary.

Soils.—The soils of the district may be divided into three classes (1) The red coloured laterite soil found on the hills as at Mahabeshwar. These soils, when irrigation facilities are available, yield good garden crops like the vegetables, etc. (2) The black or *Kali* soil found in belts along the streams. In the Krishna valley is found the broadest belt of this rich soil which yields the best garden and dry crops in the district. It is formed from the washings of the upland countries during the monsoon and washed down by the floods into the valleys. The soil is naturally, therefore, very rich fertile and some of the best crops of the Deccan are grown here. Some of the best *jowar* of the Presidency is grown on this soil. *Jowar* forms the staple crop although other crops are also grown. (3) The third soil is the lighter black soil. This kind of soil is found on the eastward part of the district along the out-slopes of the hills and the plains. *Bajri* (in Man Taluka) and *jowar* form the staple crops.

So far only a few samples of soils from the Satara district have been analysed but they all resemble those of their class found in the Poona District. Figures of analyses of typical soils are given below :—

TABLE NO. 87.

	Red laterite soil.	Black soil.	Black subsoil	Garden soil.
	Per cent.	Per cent.	Per cent.	Per cent.
Loss on ignition	11.59	..	..	11.36
Sand and insoluble silicates	40.13	56.66	59.16	73.48
Lime .. ..	..	..	..	1.80
Potash	0.52	0.33	0.39	0.92
Phosphoric acid	0.13	0.25	0.28	0.39
Nitrogen	0.02	0.05	0.05	0.16

The red laterite soil which has given only 40·13 per cent. of sand and insoluble silicates contains a large percentage of alumina and iron which are not shown in the above table. The high per cent. of loss on ignition is due to alumina and iron which hold water as hydrated compounds. The quantities of potash and phosphoric acid are quite good. The nitrogen per cent. is small but as the vegetables are grown with the aid of organic manure the deficiency of nitrogen is made up. The remaining three soils have all a good supply of plant food constituents. The black soil and subsoil are very retentive as shown by the small per cent. of sand and insoluble silicates while the garden soil with 73·48 per cent. of insoluble mineral matter is well drained as required for garden crops.

(G) Sholapur District.

Area.—The district of Sholapur lies between 17° 8' and 18° 33' north latitude and 74° 37' and 76° 26' east longitude and occupies an area of 4,556 square miles.

Physical features and rainfall.—Except some parts of Barsi, Madha, Malsiras and Karmala where there is a good deal of hilly ground, the district is generally flat or undulating. The annual rainfall is about 25 inches average and is on the whole scanty and uncertain.

Rocks.—Prevailing rock is the Deccan Trap with its varieties found in other parts of the Deccan.

Soils.—The soils of the Sholapur district are of three kinds: black, coarse gray and reddish. The black soil is chiefly found on the banks of rivers and streams. The Barsi taluka is mostly occupied by black soil. These deep soils with careful tillage and with seasonable rain can yield rich crops. In Sangola and Malsiras Talukas where the soils are light and stony they yield only early monsoon crops but generally the whole district is used for growing *rabi* crops.

Following is the variation found in the chemical composition of the Sholapur black soils:—

TABLE NO. 88.

Chemical Analysis.

	Per cent.
Loss on ignition	17·46 to 18·90
Sand and insoluble silicates	44·02 to 61·32
Lime	2·40 to 6·04
Potash	0·27 to 0·54
Phosphoric acid	0·15 to 0·31
Nitrogen	0·03 to 0·05

The figures clearly show that the soils are rich in plant food constituents except nitrogen and are also retentive and therefore with good rainfall yield excellent crops.

CHAPTER V.

SOILS OF THE WESTERN COAST DISTRICTS.

The Western Coast of the Bombay Presidency includes Thana, Kolaba, Ratnagiri and North Kanara Districts and also the Goa Territory. It extends north-south as a long strip between the crest of the Sahyadri mountains on the east and the Arabian sea on the west. The whole of the area is subject to heavy rainfalls during the months of June to October. The soils show variation according to the underlying rocks and their position between the hills on one hand and the sea on the other.

(A) Thana District.

Area.—The district of Thana lies between 18° 53' and 20° 22' north latitude and 72° 39' and 73° 48' east longitude and covers an area of 3,576 square miles.

Physical features and climate.—Thana consists of a distinct strip of low land intersected by hilly tracts. The northern half of the district is more flat than the southern half. The mean temperature 83° F. ranges from 58° F. in January to 103° F. in April. The climate is moist. The rainfall ranges from 66 to 100 inches.

Rocks.—The prevailing rock in the Thana district is the Deccan trap with all its varieties. In a few places on the coast line there are, here and there alluvial rocky materials.

Soils.—There are three main types of soils. The black coloured soils in the plains are used for rice. Lighter coloured soils which are found on the hill tops and hill slopes, are used for inferior millets. These are called *Varkas*. Along the coast there are black coloured soils of lighter type and they are used for garden crops.

The chemical composition of rice soils and sub-soils is given below. The variation shown is from twelve soils :—

TABLE NO. 89.

	Soils.		Sub-soils.	
	Minima.	Maxima.	Minima.	Maxima.
	Per cent.	Per cent.	Per cent.	Per cent.
Silica and insoluble silicates	66.70	87.28	66.34	80.54
Lime	0.20	2.88	0.39	1.40
Potash	0.58	1.00	0.43	1.00
Phosphoric acid	0.12	0.59	0.07	0.18
Nitrogen	0.03	0.22	0.04	0.17

Both the soils and the sub-soils show a good deal of variation but on the whole they are fairly well in lime, and good in potash and phosphoric acid. Some soils are poor in nitrogen while others are rich in that

constituent. This variation is due to washing of the material from certain parts and their accumulation in other parts. In one case soil samples were specially collected to see whether this kind of variation was common. Twelve samples were collected from the rice breeding portion of the Karjat Farm in Thana District and it was found that wherever silt had accumulated the nitrogen varied from 0·09 to 0·12 per cent. while where there was but little silt the nitrogen varied from 0·04 to 0·07 per cent.

The following table gives mechanical separates of typical rice soils. The figures are from 12 samples :—

TABLE No. 90.

	Minima.	Maxima.
Clay finest silt and fine silt	14·28	19·92
Medium silt	10·90	16·20
Coarse silt	20·67	32·72
Fine sand	22·48	27·19
Coarse sand	9·48	18·96

The figures indicate that the soils are all alike. They are well drained but contain enough of fine matter to make them sufficiently retentive of moisture and plant food constituents.

Garden soils in the Thana District are not all of the same nature. Those near Kalyan or on the coast line where the garden cultivation is well developed as at Bassein the soils are rich while the soils under garden cultivation in other parts of the district are comparatively poor. The following table gives the figures for a typical garden at Bassein representing the gardens on the coast line and the variation found in the composition of garden soils near Kalyan.

TABLE No. 91.

	Bassein Garden.	Kalyan Gardens.	
		Minima.	Maxima.
	Per cent.	Per cent.	Per cent.
Sand	69·16	70·18	75·22
Lime	1·00	0·80	2·20
Potash	0·66	0·43	0·68
Phosphoric acid	0·43	0·40	0·68
Nitrogen	0·12	0·10	0·16

The soils are rich in nitrogen, potash and phosphoric acid and fairly good in lime. The other soils in the district show the following variations:—

TABLE No. 92.

	Minima.	Maxima.	Remarks.
	Per cent.	Per cent.	
Sand	45.25	52.50	
Lime	0.28	0.84	
Potash	0.46	0.70	
Phosphoric acid	0.06	0.12	
Nitrogen	0.05	0.09	One sample gave 0.03.

These soils contain less of sand than the above samples. They are rich in potash, fair in phosphoric acid, nitrogen and lime.

(B) Koliaba District.

Area.—The district of Kolaba lies between 17° 51' and 19° 8' north latitude and 72° 51' and 73° 45' east longitude. It occupies an area of 2,167 square miles.

Physical features and climate.—Kolaba district is a rugged belt of country from fifteen to thirty miles broad. It is situated between the western Ghats and the sea. There are several spurs running westwards at right angles to the main range. The temperature varies from 65° F. in January to 92° F. in May. The rainfall on the coast is 90 inches, while in the hills it is heavier still.

Rocks.—The rock in the Kolaba District is all trap with small caps of laterite on some hills.

Soils.—There are three types of soils derived from the trap in this district. The black coloured soil which is fairly deep and productive is used for growing rice. Light reddish coloured soil which is shallow is on the sides and slopes of hills and is used for inferior millets. The third type of soil is called "manat". It is clayey and very deep. In the rainy season it is inaccessible and in the dry season it is too stiff to be cultivated.

The composition of rice soils from Alibag Farm is given in the following table. The figures are from four soils:—

TABLE No. 93.

	Soils.		Sub-soils.	
	Minima.	Maxima.	Minima.	Maxima.
	Per cent.	Per cent.	Per cent.	Per cent.
Organic matter	1.64	2.64	1.00	2.55
Silica and insoluble silicates	44.52	57.72	45.38	55.10
Lime	0.24	1.40	0.28	0.89
Potash	0.12	0.74	0.12	0.58
Phosphoric acid	0.06	0.14	0.04	0.04
Nitrogen	0.01	0.06	0.01	0.04

These soils and sub-soils are very much like each other. They are poor in nitrogen and phosphoric acid, medium in lime and rich in potash.

The mechanical analysis of the above soils and sub-soils from the Alibag Farm gave the following separates :—

TABLE No. 94.

	Soils.		Sub-soils.	
	Minima.	Maxima.	Minima.	Maxima.
	Per cent.	Per cent.	Per cent.	Per cent.
Finest silt and clay	6.90	10.05	6.61	9.96
Fine silt	1.52	3.85	1.79	2.16
Medium silt	1.91	2.45	2.34	7.69
Coarse silt	7.74	24.60	11.01	18.20
Fine sand	33.31	45.37	29.13	40.91
Coarse sand	14.22	49.39	22.91	41.65

The soils and the sub-soils are both alike in their character. The separates which make the soils retentive are small in quantity while the proportion of those that make the soils porous is high. They are, however, not of the type as are described to be hungry. The proportion of fine sand to coarse sand is good and there is enough of coarse silt. These two factors make the soils suitable for rice growing.

The other rice soils in the Kolaba district give the following variation for nine soils :—

TABLE No. 95.

	Minima.	Maxima.	Remarks.
	Per cent.	Per cent.	
Loss on ignition	10.44	15.36	
Silica and insoluble silicates	63.68	73.08	One sample gave 57.83.
Lime	0.40	1.0	One sample gave 0.02.
Potash	0.43	0.78	
Phosphoric acid	0.10	0.46	
Nitrogen	0.06	0.11	

These soils are fairly good in all the plant food constituents although they contain a high percentage of sand.

The following are the only figures of two typical *Varkas* soils in the Kolaba district :—

TABLE No. 96.

	I	II.
	Per cent.	Per cent.
Silica and insoluble silicates	52.72	57.20
Potash	0.31	0.39
Phosphoric acid	0.20	0.23
Nitrogen	0.02	0.07

Soil number one is poor in Nitrogen but both the soils are good in potash and phosphoric acid.

There are some sticky clayey soils found here and there in the district. They are called *manat*. These have been considered in Chapter II.

(C) Ratnagiri District.

Area.—The district of Ratnagiri lies between 15° 44' and 18° 4' north latitude and 73° 2' and 73° 57' east longitude and covers an area of very nearly four thousand square miles.

Physical features.—Near the coast, the Ratnagiri District consists of bare elevated plateau, intersected by numerous creeks and rivers. Ten miles inland the country becomes more open but a little further it is occupied by spurs of the western Ghats.

Climate and rainfall.—The climate is moist. Along the coast the average annual rainfall varies from 80 to 105 inches but farther inland it rises to 140 inches and in the Ghats it is still more.

Rocks.—The most important rocks of the Ratnagiri District are laterite, the Deccan Trap and the gneissic rocks. The laterite which extends from the coast to about 15 miles east of Ratnagiri occupies the largest area. The Deccan trap is seen only in high scraps of the Sahyadri. In the Ratnagiri District it is not exposed as it is covered in most places by laterite. The gneissic rocks are exposed in the southern parts along the coast line.

Soils.—Most of the soils of the Ratnagiri District may be considered to be wholly derived from laterite. There are four types of soils: (1) the rice soils varying in colour from yellowish to red brown getting darker inland as we approach the trap, (2) the garden soils, (3) the *varkas* soils and (4) alluvial soils met along the banks of rivers and along the coast line.

According to the classification given in the Statistical Atlas the rice soils are divided into *mali*, *panthal*, *kuryat*, *pulanvat* and *kharevat*. They are mostly of the same type and *kuryat* is perhaps the general type of well drained rice soils on slopes or at the foot of the hills. *Mali* soil is found on level lands, it is able to retain moisture while *panthal* is a low-lying land. *Pulanvat* is sandy and is found only on the coast. *Kharevat* soil as its name indicates contains salt and grows only a coarse red rice.

Following are the analyses of two typical rice soils; one from Ratnagiri and the other from Dabhol:—

TABLE No. 97.

	Ratnagiri rice soil.	Dabhol ¹ rice soil.
	Per cent.	Per cent.
Loss on ignition	13.90	17.06
Silica and insoluble silicates	72.22	65.68
Lime	0.78	0.04
Potash	0.46	0.43
Phosphoric acid	0.10	0.37
Nitrogen	0.11	0.14

The Dabhol soil is deficient in lime but contains less sand and more phosphoric acid and nitrogen than the Ratnagiri soil. Both the soils, however, are rich in potash, phosphoric acid and nitrogen.

The mechanical analysis of the above soils and sub-soils from the Alibag Farm gave the following separates :—

TABLE NO. 94.

	Soils.		Sub-soils.	
	Minima.	Maxima.	Minima.	Maxima.
	Per cent.	Per cent.	Per cent.	Per cent.
Finest silt and clay	6.90	10.05	6.61	9.96
Fine silt	1.52	3.85	1.79	2.16
Medium silt	1.91	2.45	2.34	7.69
Coarse silt	7.74	24.60	11.01	18.20
Fine sand	33.31	45.37	29.13	40.91
Coarse sand	14.22	49.39	22.91	41.65

The soils and the sub-soils are both alike in their character. The separates which make the soils retentive are small in quantity while the proportion of those that make the soils porous is high. They are, however, not of the type as are described to be hungry. The proportion of fine sand to coarse sand is good and there is enough of coarse silt. These two factors make the soils suitable for rice growing.

The other rice soils in the Kolaba district give the following variation for nine soils :—

TABLE NO. 95.

	Minima.	Maxima.	Remarks.
	Per cent.	Per cent.	
Loss on ignition	10.44	15.36	
Silica and insoluble silicates	63.68	73.08	One sample gave 57.88.
Lime	0.40	1.0	One sample gave 0.02.
Potash	0.43	0.78	
Phosphoric acid	0.10	0.46	
Nitrogen	0.06	0.11	

These soils are fairly good in all the plant food constituents although they contain a high percentage of sand.

The following are the only figures of two typical *Varkas* soils in the Kolaba district :—

TABLE NO. 96.

	I	II.
	Per cent.	Per cent.
Silica and insoluble silicates	52.72	57.20
Potash	0.31	0.39
Phosphoric acid	0.20	0.23
Nitrogen	0.02	0.07

Soil number one is poor in Nitrogen but both the soils are good in potash and phosphoric acid.

There are some sticky clayey soils found here and there in the district. They are called *manat*. These have been considered in Chapter II.

(C) Ratnagiri District.

Area.—The district of Ratnagiri lies between 15° 44' and 18° 4' north latitude and 73° 2' and 73° 57' east longitude and covers an area of very nearly four thousand square miles.

Physical features.—Near the coast, the Ratnagiri District consists of bare elevated plateau, intersected by numerous creeks and rivers. Ten miles inland the country becomes more open but a little further it is occupied by spurs of the western Ghats.

Climate and rainfall.—The climate is moist. Along the coast the average annual rainfall varies from 80 to 105 inches but farther inland it rises to 140 inches and in the Ghats it is still more.

Rocks.—The most important rocks of the Ratnagiri District are laterite, the Deccan Trap and the gneissic rocks. The laterite which extends from the coast to about 15 miles east of Ratnagiri occupies the largest area. The Deccan trap is seen only in high scraps of the Sahyadri. In the Ratnagiri District it is not exposed as it is covered in most places by laterite. The gneissic rocks are exposed in the southern parts along the coast line.

Soils.—Most of the soils of the Ratnagiri District may be considered to be wholly derived from laterite. There are four types of soils: (1) the rice soils varying in colour from yellowish to red brown getting darker inland as we approach the trap, (2) the garden soils, (3) the *varkas* soils and (4) alluvial soils met along the banks of rivers and along the coast line.

According to the classification given in the Statistical Atlas the rice soils are divided into *mali*, *panthal*, *kuryat*, *pulanvat* and *kharvat*. They are mostly of the same type and *kuryat* is perhaps the general type of well drained rice soils on slopes or at the foot of the hills. *Mali* soil is found on level lands, it is able to retain moisture while *panthal* is a low-lying land. *Pulanvat* is sandy and is found only on the coast. *Kharvat* soil as its name indicates contains salt and grows only a coarse red rice.

Following are the analyses of two typical rice soils; one from Ratnagiri and the other from Dabhol:—

TABLE NO. 97.

	Ratnagiri rice soil.	Dabhol Rice soil.
	Per cent.	Per cent.
Loss on ignition	13·90	17·06
Silica and insoluble silicates	72·22	65·68
Lime	0·73	0·64
Potash	0·46	0·43
Phosphoric acid	0·10	0·37
Nitrogen	0·11	0·14

The Dabhol soil is deficient in lime but contains less sand and more phosphoric acid and nitrogen than the Ratnagiri soil. Both the soils, however, are rich in potash, phosphoric acid and nitrogen.

Leaving out Dabhol, if we take the other rice soils of the Ratnagiri District they give the following variation in fourteen soils :—

TABLE No. 98.

				Minima.	Maxima.
				Per cent.	Per cent.
Loss on ignition	..	..	..	12·62	17·16
Sand	..	..	..	71·30	77·32
Lime	..	..	..	0·78	2·80
Potash	..	..	..	0·43	0·82
Phosphoric acid	..	..	..	0·10	0·46
Nitrogen	..	..	..	0·11	0·26

The rice soils of Ratnagiri district are rich in plant food constituents except perhaps lime, although the percentage of sand in those soils is high.

The mechanical analysis which is given below shows that although coarse material is present in large quantities still there is enough of very fine clayey material to retain plant food constituents :—

TABLE No. 99.

				Minima.	Maxima.
				Per cent.	Per cent.
Clay and finest silt	..	..	..	6·60	6·90
Fine silt	..	..	..	2·10	2·45
Medium silt	..	..	..	1·70	3·00
Coarse silt	..	..	..	2·24	9·14
Fine sand	..	..	..	9·36	11·51
Coarse sand	..	..	..	67·00	78·00

The *mal* soils which are considered to be better type of rice soils give the following analysis of four soils :—

TABLE No. 100.

				Minima.	Maxima.
				Per cent.	Per cent.
Loss on ignition	..	..	..	16·96	21·08
Silica and insoluble silicates	..	..	..	57·80	69·48
Lime	..	..	..	0·30	0·50
Potash	..	..	..	0·16	0·43
Phosphoric acid	..	..	..	0·01	0·04
Nitrogen	..	..	..	0·10	0·10

These contain less of sand but in other ways they are not better than the other rice soils.

The garden soils do not differ from each other in their composition. The following is the variation shown by six typical soils:—

TABLE NO. 101.

				Minima.	Maxima.
				Per cent.	Per cent.
Loss on ignition	..	..	..	15.62	19.74
Sand	..	..	..	55.72	63.66
Lime	..	..	..	Traces	0.04
Potash	..	..	..	0.23	0.58
Phosphoric acid	..	..	..	0.32	0.52
Nitrogen	..	..	..	0.11	0.22

These soils have less of sand than the rice soils. They are poor or deficient in lime but rich in other plant food constituents. On the garden soils the chief crops grown are the cocoanut and the betel palm.

Varkas soils on the uplands are described as light and poor. Coarse grains like *nachani*, and *vari* are grown on these. A three or four year rotation of crop is taken on these lands after which they lie fallow for some years. From the description usually given it seems that the soils contain but very little of plant food constituents but the analytical figures show just the reverse. The variations shown by 8 typical samples of *varkas* are given in the table below:—

TABLE NO. 102.

				Minima.	Maxima.	Remarks.
				Per cent.	Per cent.	
Loss on ignition	..	..	..	11.50	17.44	
Sand	..	..	..	69.42	78.06	
Lime	..	..	..	1.0	3.30	One sample gave 0.08 per cent.
Potash	..	..	..	0.19	0.89	
Phosphoric acid	..	..	..	0.17	0.48	
Nitrogen	..	..	..	0.08	0.22	

These figures go to prove that the *varkas* soils contain enough of plant food constituents but perhaps they are not in an available condition or it may be that the washing action of the heavy rain is so strong as to remove the plant food materials when they become available and thus leave the crops to feed on unavailable material.

(D) Kanara District.

Area.—The District of Kanara lies between 13° 53' and 15° 32' north latitude and 74° 4' and 75° 5' east longitude and has an area of 3,945 square miles.

Physical features.—The district consists of two widely differing tracts one above and the other below the Ghats. The below-ghat portion is a fairly level plain along the coast from five to ten miles in breadth. Near the Ghats it breaks up into hills and valleys. In the up-ghat country the northern part is forest, while the southern part is covered with spice gardens.

Climate and rainfall.—The temperature varies from 59° F. in November to 91° F. in May. On the coast the rainfall varies from 125 to 150 inches. On some crests of the Ghats it is 300 inches, but generally in the up-ghat country it is about 100 inches.

Rocks.—The rock found in abundance in this district is laterite or some kind of iron clay. The tops of hills are capped with laterite. Shales of various colours are found underneath the laterite and these are exposed in valleys. Clay schist is common. This crumbles into a shaly material. There are various types of schists or schistose slates. Granite is found especially along the coast line.

Soils.—Soils of the forests and the *betta* forests. The term *betta* forest is used to indicate that portion of the forest which is attached to gardens for the purpose of supplying leaf manure. The soils of the forests and the *betta* forests are derived either from laterite or from a mixture of laterite and shale. They are gritty and usually of a dry and hungry character quite unsuited for gardens. The analysis of two typical soils and the minimum and the maximum quantities of the various constituents in such soils as found from a large number of analyses are given below. These soils were taken from the neighbourhood of Sirsi.

TABLE No. 103.

	Forest soil.	<i>Betta</i> soil.	Minima.	Maxima.
	Per cent.	Per cent.	Per cent.	Per cent.
Loss on ignition	12·8	7·6	6·2	12·8
Sand and insoluble silicates	69·7	73·3	69·7	80·9
Oxide of Iron	4·5	5·3	2·7	5·6
Alumina	12·7	14·0	8·8	14·0
Lime	0·11	0·06	0·03	0·11
Potash	0·58	0·29	0·21	0·58
Phosphoric acid	0·035	0·052	0·035	0·056
Nitrogen	0·14	0·09	0·06	0·14

The mechanical analysis of these gave the following percentages of the various separates:—

TABLE NO. 104.

	Forest soil.	Betta soil.
	Per cent.	Per cent.
Clay, finest and fine silt.	4.3	3.7
Medium silt	3.8	3.5
Coarse silt	3.9	4.5
Fine sand	8.7	13.5
Coarse sand	79.3	74.8

These soils may differ from each other but as the figures indicate they are all coarse, hungry soils, poor in lime and phosphoric acid but having a sufficient quantity of organic matter, nitrogen and potash. These soils are unsuited to any system of cultivation and would only be suitable for forest or large tree growth.

In the neighbourhood of the hill forests are the deep moist valleys containing the garden lands on which spice cultivation is carried on. These gardens lie between hills covered with evergreen forests. These valleys gradually widen out into flat areas on which the food crops of the people are produced. The garden soils are derived from shales overlying schistose slates. The soils are slowly washed away but they are then replaced by the decomposed shale dug out from the sides of the gardens. The following table includes two typical garden soils with one sub-soil and also the maxima and minima percentages of constituents from 8 soils:—

TABLE NO. 105.

	1 A garden soil at Sirsi.	2 Sub-soil under 1.	A garden soil 6 miles north- east of Sirsi.	Minima.	Maxima.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Loss on ignition	6.7	7.9	6.6	5.6	8.2
Sand and insoluble silicates	76.0	72.3	74.6	72.0	81.7
Oxide of Iron	4.9	6.7	5.3	2.0	10.7
Alumina	11.3	13.3	13.0	9.3	16.4
Lime	0.03	0.03	0.08	0.03	0.12
Potash	0.44	0.61	0.36	0.29	0.69
Phosphoric acid	0.05	0.06	0.05	0.04	0.09
Nitrogen	0.15	0.09	0.10	0.08	0.15

The mechanical analysis of the above are :—

TABLE NO. 106.

	A garden soil at Sirsi.	Sub-soil under 1.	A garden soil 6 miles north-east of Sirsi.
	Per cent.	Per cent.	Per cent.
Clay, finest and fine silt	19.3	26.1	15.3
Medium silt	5.8	6.7	6.0
Coarse silt	7.4	8.9	8.1
Fine sand	19.6	19.2	15.6
Coarse sand	47.9	39.1	55.0

There is very little difference in the chemical composition of the forest lands and the garden lands. The garden lands are poor in lime and phosphoric acid and contain sufficient potash and nitrogen but the great difference is exhibited by the mechanical analysis. In the forest soils the proportion of separates which tend to increase porosity to separate which tend to increase retentiveness is as 75 to 25 while the proportion of these two in the garden lands is 50 to 50. All the figures clearly indicate the characters of the typical porous though retentive. The sub-soils of these are very similar to soils.

As indicated above, owing to heavy rainfall, it is necessary to fill up the beds of the gardens with new earth. The material used for this purpose is obtained from the cuttings in the hills at the sides of the gardens. The material is locally known as *Kagadali*. It varies in colour from yellow, to brown to red. The following are the minima and maxima of the constituents as determined in four samples :—

TABLE NO. 107.

	Minima.	Maxima.
	Per cent.	Per cent.
Loss on ignition	5.0	9.9
Sand and insoluble silicates	65.1	82.6
Oxide of Iron	2.5	9.6
Alumina	9.5	18.4
Lime	0.03	0.07
Potash	0.21	0.60
Phosphoric acid	0.035	0.075
Nitrogen	0.05	0.12

The mechanical analyses of these are :—

TABLE No. 108.

	Kagadali.		Soils.	
	1	2	3	4
	Per cent.	Per cent.	Per cent.	Per cent.
Clay, finest and fine silt	11.6	34.4	25.6	17.2
Medium silt	6.7	8.0	7.4	17.4
Coarse silt	13.0	12.8	9.8	7.4
Fine sand	30.7	17.3	17.7	16.7
Coarse sand	38.0	27.5	49.5	41.4

It is clear from the figures that the constituents in the *kagadali* are very much like those in the garden soils but the *kagadali* contains a higher proportion of those separates which tend to increase the retentiveness than the garden soils. The *kagadali* when spread on garden lands seems to change into a more porous material.

At the mouth of the valleys and down in the plains rice is a very prominent crop yet there are certain portions of land which are put under gardens, but these do not differ from the rice lands in their chemical analysis. The following are a few typical soils of the plains of the North Kanara District :—

TABLE No. 109.

	Karwar.	Ankola.
	Per cent.	Per cent.
Loss on ignition	6.74	5.56
Sand and insoluble silicates	85.12	83.22
Lime	0.67	0.06
Potash	0.37	0.39
Phosphoric acid	0.12	0.13
Nitrogen	0.13	0.08

As many as 18 samples of soils were analysed from Kumta. The minima and maxima of constituents are given below :—

TABLE No. 110.

	Minima.	Maxima.
	Per cent.	Per cent.
Loss on ignition	5.27	8.22
Sand and insoluble silicates	58.14	64.19
Lime	0.15	0.25
Potash	0.32	0.64
Phosphoric acid	0.11	0.14
Nitrogen	0.10	0.16

These soils are good in nitrogen and phosphoric acid, rich in potash and fair in lime.

(E) Goa Territory.

Laterite is the principal rock from which the Goa soils are derived. There are other rocks also found here and there. They are granite, gneiss trap and shale. Alluvial deposits of recent origin are met with along the sea coast and also on the borders of rivers and streams. The whole territory may be divided into two sections, one forming the hilly tract and the other comprising the flat area on the coast. Several samples of soils were received under these labels. The following tables give the analyses of the soils of these two typical tracts :—

TABLE NO. 111.

	Soils of hilly tract.		Sub-soils of hilly tract.	
	Minima.	Maxima.	Minima.	Maxima.
	Per cent.	Per cent.	Per cent.	Per cent.
Organic matter *	2.61	5.08	2.87	3.85
Sand and insoluble silicates	64.72	79.28	65.22	74.46
Lime	0.60	1.40	0.60	1.00
Potash	0.50	0.85	0.54	0.82
Phosphoric acid	0.32	0.45	0.21	0.71
Nitrogen	0.14	0.16	0.12	0.22

* In these determinations organic matter was determined and not the Loss on ignition.

Seven soils and sub-soils under them from the flat tract of Goa territory were analysed. These figures are given below :—

TABLE NO. 112.

	Seven soils from flat tract.		Seven sub-soils from flat tract.	
	Minima.	Maxima.	Minima.	Maxima.
	Per cent.	Per cent.	Per cent.	Per cent.
Loss on ignition *	9.48	13.40	9.68	11.06
Sand and insoluble silicates	65.96	77.72	64.18	73.30
Potash	0.34	0.85	0.35	0.97
Phosphoric acid	0.20	0.61	0.11	0.62
Nitrogen	0.16	0.26	0.12	0.19

* Loss on ignition was determined on five samples only.

In the case of these soils the lime showed a great variation and hence the lime percentages are tabulated separately to avoid misunderstanding.

Lime percentage in the various soils and the sub-soils under them were found to be as follows:—

TABLE NO. 113.

—	1	2	3	4	5	6	7
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Soil ..	0.80	6.90	6.40	0.02	0.01	0.01	0.02
Sub-soil ..	0.60	3.60	3.00	0.04	0.02	0.01	0.04

All these figures show that the soils and the sub-soils of both the hilly tract and the flat tract have sufficiently large quantities of potash, phosphoric acid and nitrogen and they contain enough of organic matter. In the hilly tract soils, the lime is not quite deficient but in the flat tract soils, the lime shows a tendency to concentrate in certain parts and hence some soils contain as much as 6.90 per cent. of lime, while there are others which contain but only 0.01 per cent. of lime. Many soils in this tract may be found to be defective in their lime contents.

Rao Bahadur G. K. Kelkar, who was once Professor of Agriculture at the Poona Agricultural College worked for a period of three years in the Goa territory as an agricultural expert. During the period he was there he sent some typical samples of *Varkas* soils (from lands where *Nachani* is grown), cocoanut soils and rice soils.

The *Varkas* sub-soils gave nearly the same figures as the soils. The following table gives the minima and the maxima of figures of six samples.

TABLE NO. 114.

Chemical Composition of Varkas Soils.

—	Minima.	Maxima.
	Per cent.	Per cent.
Moisture ..	0.88	4.06
Loss on ignition ..	2.96	9.80
Sand ..	34.70	48.94
Lime CaO ..	0.09	0.39
Potash ..	0.02	0.52
Phosphoric acid ..	0.02	0.27
Nitrogen ..	0.03	0.09

The samples do not contain much of sand but they are poor in lime. They contain medium quantities of nitrogen. Some of the soils are poor in phosphoric acid and potash, while others are rich in these constituents. There is a good deal of variation in the soils.

TABLE No. 115.

Mechanical Analysis.

					Minima.	Maxima.
					Per cent.	Per cent.
Stones	..	..	..	..	10·0	48·0
					One fine	matter
Finest and fine silt	..	..	..	..	11·46	27·69
Medium silt	..	..	..	..	6·14	10·0
Coarse silt	..	..	..	..	13·60	20·73
Fine sand	..	..	..	..	40·17	65·07
Coarse sand	..	..	..	..	7·77	11·76

The coarse material is more than the fine material.

There are many coconut plantations in the Goa territory and hence six samples of soils from typical gardens were analysed and the variation is shown below :—

TABLE No. 116.

Chemical Analysis.

					Minima.	Maxima.	Remarks.
					Per cent.	Per cent.	
Moisture	..	..	..	..	0·12	3·24	
Loss on ignition	..	..	..	..	0·68	3·80	
Sand	..	..	..	..	90·76	96·14	
Lime CaO	..	..	..	..	0·17	0·30	One sample gave 0·05 per cent. and another 1·01 per cent.
Potash	..	..	..	..	0·02	0·08	One sample gave 0·12 per cent.
Phosphoric acid	..	..	..	..	0·02	0·06	One sample gave 0·11 per cent.
Nitrogen	..	..	..	..	0·02	0·09	

These coconut soils are poor to moderately rich in nitrogen. They are all poor in potash, phosphoric acid and lime.

Rice is an important crop in the Goa Territory. Soils and sub-soils from seven different places were collected for analysis.

There are two types amongst these soils. One type is more sandy than the other and hence the soils of the two groups differ from each other while within the group they are similar.

TABLE NO. 117.

Chemical Composition.

	Coarser type of soils.		Finer type of soils.	
	Minima.	Maxima.	Minima.	Maxima.
	Per cent.	Per cent.	Per cent.	Per cent.
Moisture	0.30	2.24	2.00	3.46
Loss on ignition	0.12	2.05	6.07	8.40
Sand	75.77	93.2	37.77	63.31
Lime	0.10	0.33	0.22	0.35
Potash	0.03	0.07	0.18	0.52
Phosphoric acid	0.02	0.04	0.11	0.37
Nitrogen	0.03	0.04	0.09	0.11

TABLE NO. 118.

Mechanical Analysis.

	Coarser type of soils.		Finer type of soils.	
	Minima.	Maxima.	Minima.	Maxima.
	Per cent.	Per cent.	Per cent.	Per cent.
			On fine matter	
Finest and fine silt	3.55	6.50	15.49	45.14
Medium silt	2.21	3.09	6.46	15.89
Course silt	2.98	13.09	17.51	30.24
Fine sand	67.36	75.94	14.64	48.42
Coarse sand	2.08	20.65	6.50	17.73

It will be seen from the above figures that the coarser soils contain smaller proportions of those separates which tend to increase the retentive power of the soil while the finer type soils naturally contain more of the separates which tend to increase the retentive power. Both the types of soils contain small quantities of lime. The coarser type soils are poor in nitrogen and phosphoric acid and nearly poor in potash, but the finer type of soils are fairly rich in nitrogen, potash and phosphoric acid.

CHAPTER VI.

THE KARNATAK DISTRICTS.

The Karnatak includes Belgaum, Dharwar and Bijapur districts. Many of the most important rock formations, from the oldest granites to the laterite and the newest alluvium are met with in this division.

(A) Belgaum District.

Area.—The district of Belgaum lies between 15° 22' and 16° 58' north latitude and 74° 2' and 75° 25' east longitude and covers an area of 4,614 square miles.

Physical features and rainfall.—The country forms a large plain studded with solitary hills. The most elevated portion of the district lies to the west and the surface of the plain slopes towards the east. The rainfall at Belgaum itself is about 50 inches. In the east it goes down to twenty-five inches while in the extreme west it goes up to about 100 inches.

Rocks.—There are three prominent systems of rocks in the Belgaum District. The northern and the north-western part is occupied by trap which is in many places covered with laterite. The eastern part is occupied by the *Kaladgi* rocks consisting chiefly of sandstones and limestones over lying schistose rocks. The southernmost part of the district is occupied by the granite and gneissic rocks.

Soils.—The soils of the district are derived from the trap, laterite, granite and the sandstone and many of them are mixtures of soils derived from the rocks mentioned. The red soils are the result of the decomposition of laterite and they are generally found along the western border. These soils are generally poor but with heavy rainfall of the western ghats grow *kharif* crops. Where the red soils, as at Belgaum, are formed from the mixture of decomposed materials from both the trap and the laterite, they grow excellent garden crops under well irrigation. The trap soils are black or light as in other districts which have trap soils. The soils formed from the mixture of decomposed materials from trap and sandstone are found to be very good for garden crops.

Red coloured soils growing garden crops under irrigation are derived mainly from laterite but they have generally some mixture of material derived from trap. The analysis of a representative sample of laterite from Belgaum is as follows ;—

TABLE No. 119.

	Laterite Soil.	Laterite Sub-soil.
	Per cent.	Per cent.
Moisture	6·20	5·80
Loss on ignition	8·30	10·12
Sand and insoluble silicates	49·88	50·70

TABLE NO. 119—*contd.*

					Laterite Soil.	Laterite Sub-soil.
					Per cent.	Per cent.
Lime	..	..	..	..	0·17	0·17
Magnesia	..	..	..	..	0·50	0·30
Potash	..	..	..	..	0·27	0·25
Phosphoric acid	..	..	..	..	0·28	0·32
Nitrogen	..	..	..	..	0·11	0·11

Although poor in lime the soil is quite good in potash, phosphoric acid and nitrogen.

The mechanical condition of the soils shows that they are well drained and hence can with advantage be irrigated.

TABLE NO. 120.

					Laterite.	
					Soil.	Sub-soil.
					Per cent.	Per cent.
Clay and finest silt	..	..	..	..	43·36	31·46
Fine silt	..	..	..	..	5·14	4·68
Medium silt	..	..	..	..	10·66	8·86
Coarse silt	..	..	..	..	9·27	13·53
Fine sand	..	..	..	..	18·27	22·02
Coarse sand	..	..	..	..	13·30	19·45

In these soils the constituents which increase the retentivity are balanced by the constituents which decrease the retentivity and are therefore in the best condition for garden crops.

The black soils of the Belgaum District are derived from the trap. In the Athani Taluka they yield excellent crops both irrigated and non-irrigated. Their analysis is given below:—

TABLE NO. 121.

					Black Garden Soil.	
					Per cent.	
Organic matter	..	..	..	..	1·07	
Sand	..	..	..	..	48·00	
Lime	..	..	..	..	5·49	
Potash	..	..	..	..	0·70	
Phosphoric acid	..	..	..	..	0·25	
Nitrogen	..	..	..	..	0·06	

The soils is quite good in the various plant food constituents.
A typical sandstone soil in the Belgaum district is as follows :—

TABLE NO. 122.

Chemical Analysis.

			Sandstone Soil.
			Per cent.
Loss on ignition	..	..	3·32
Sand	..	..	88·54
Lime	..	..	0·23
Potash	..	..	0·56
Phosphoric acid	..	..	0·06
Nitrogen	..	..	0·005

TABLE NO. 123.

Mechanical Analysis.

			Sandstone Soil.
			Per cent.
Clay and finest silt	..	..	2·24
Fine silt	..	..	2·46
Medium silt	..	..	3·44
Coarse silt	..	..	2·15
Fine sand	..	..	30·57
Coarse sand	..	..	59·14

These soils have very little retentive power and are very poor in nitrogen, poor in lime, fair in phosphoric acid and good in potash.

(B) Dharwar District.

Area.—The district of Dharwar lies between 14° 17' and 15° 53' north latitude and 74° 43' east longitude and covers an area of 4,602 square miles.

Physical features and rainfall.—The district is composed of three regions—the *mallad*, *Desh* and the transition which lies between the other two. *Mallad* is the hilly country forming the western part. It has a heavy rainfall and grows rice and *raji* as the staple crops. The *Desh* tract includes Ron, Navalgund and Gadag talukas and is an open plane country. It is liable to drought. In normal years it produces good crops of *jowar*, cotton, wheat and oil-seeds. The transition tract is between the *Desh* and the *Mallad*, about twelve hundred square miles in extent. Where the rainfall is abundant, rice is grown; where it is scanty dry crops are raised. The rainy season for Dharwar lasts from June to December. It gets the benefit of both the south-west and the north-east monsoons.

Rocks.—Dharwar District possesses rocks of more formations than one. Granite, rocks of the transition series, sandstone, diorite, etc., are

found in small or large strips. The north-east portion of the Dharwar District is occupied chiefly by granite. Transition rocks occupy a large portion of the district. They stretch from the east and south, where they succeed the granite to the foot of the Sahyadries, being broken in places by the granite which protrudes from beneath them. In the northern part transition rocks are found at the bottom of sandstone valleys. The chief rocks of this formation are the clay slate, chlorite schist, talc schist, hæmatitic quartzite, etc.

The rocks composing the hills round Dharwar are schists passing into slates and shales. Chlorite slates and chlorite schists are widely distributed throughout the central and southern part of the district. The rocks which form the Kappatgudd hills and the neighbouring country belong to the gneissic formation. They have been subjected to immense disturbances. The diorite does not occur in great abundance. Dykes of this rock sometimes stand from the surface in long ridges, which appear like lines of rocks. Lateritic material is also found in different parts, chiefly in the west. It is found resting on granite, transition rocks, sandstone, etc. Sandstone occupies the north-east corner of the Dharwar District.

Soils.—The soils of the district are derived from mixtures of decomposed rocks of all sorts found distributed over the district. They cannot therefore be classified according to rock formations. They are generally classified into (1) red soil, (2) black soil and (3) brown soil.

The red soil is comparatively shallow and gravelly. The black soil is chiefly found in the *Desh* portion and grows cotton. The brown soil is chiefly found in the western part of the district.

The following figures show the analysis of red soils :—

TABLE No. 124.

	Raneben-	Hubli	Dharwar
	nur Soils.	Soil.	Soil.
	Per cent.	Per cent.	Per cent.
Loss on ignition .. .. .	..	7.66	..
Sand and insoluble silicates..	82.15	79.88	80.43
Lime	0.06	1.60	0.73
Potash	0.36	0.62	0.34
Phosphoric acid	0.036	0.07	0.05
Nitrogen	0.070	0.03	0.08

The soils contain high percentage of sand and insoluble silicates and therefore are quickly drained. They are rich in potash and fair in phosphoric acid and lime.

The following table gives the composition of typical cotton soils of Dharwar—deep black and medium black and also of brown coloured

rice soils at Mugad which is situated in the western part of the Dharwar district :—

TABLE NO. 125.
Chemical Analysis.

	Deep black cotton soil.	Medium black cotton soil.	Brown coloured rice soil.
	Per cent.	Per cent.	Per cent.
Loss on ignition	9.68	7.60	5.56
Silica and insoluble silicates	65.26	66.66	74.54
Iron and Alumina	15.90	18.10	16.90
Lime	1.20	0.58	0.39
Magnesia	0.74	0.64	1.04
Potash	0.37	0.39	0.43
Phosphoric acid	0.04	0.05	0.13
Nitrogen	0.06	0.09	0.11

TABLE NO. 126.
**Mechanical Analysis.*

	Medium black cotton soil.	Brown coloured rice soil.
Clay and finest silt	45.00	25.06
Fine silt	26.00	24.00
Silt	13.00	17.00
Fine sand	6.77	15.43
Coarse sand	5.67	14.95

The deep black soil is good in its retentive power as shown by the loss on ignitor. It is also good in lime and potash but fair in phosphoric acid and nitrogen. The medium black soil is low in lime, good in potash and nitrogen and fair in phosphoric acid. The rice soil is well stocked with the plant food constituents except lime.

Variation in four typical black soils from Dharwar was found as follows :—

TABLE NO. 127.

	Per cent.
Loss on ignition	7.9 to 9.7
Sand and insoluble silicates	60.7 to 70.8
Lime	4.5 to 6.2
Potash	0.13 to 0.19
Phosphoric acid	0.023 to 0.033
Nitrogen	0.042 to 0.053

The soils have a good retentive power and are rich in lime, good in potash and fair in phosphoric acid and nitrogen.

* International method.

Two typical soils from Gadag gave the following figures:—

TABLE No. 128.
Chemical Analysis.

	Red soil.	Black soil.
	Per cent.	Per cent.
Loss on ignition	5·00	6·08
Silica and insoluble silicates	79·53	71·77
Iron and Alumina	13·05	12·55
Lime	0·59	2·61
Magnesia	0·55	0·45
Potash	0·27	0·42
Phosphoric acid	0·08	0·08
Nitrogen	0·064	0·022

TABLE No. 129.
**Mechanical Analysis.*

	Red soil.
	Per cent.
Clay and finest silt	30·00
Fine silt	7·00
Silt	2·00
Fine sand	9·40
Coarse sand	43·20

(C) Bijapur District.

Area.—The district of Bijapur lies between 15° 49' and 17° 29' north latitude and 75° 19' and 76° 32' east longitude and covers an area of 5,669 square miles.

Physical features and rainfall.—The district is mostly a plane with valleys indicated by the five important rivers which cross the district. These rivers are the Bhima. The Don, the Krishna, the Ghataprabha and the Malaprabha. The southern part of the country is crossed by the low ranges of hills. The rainfall is extremely irregular both in amount and distribution. The district gets rain from both the monsoons.

Rocks.—The northern part of the district is occupied by trap. In the southern part the gneissic rock occupies the south-east, Bhima sandstones and limestone are in the east and the Kaladgi sandstones, etc., are in the south-west.

Soils.—By far the greatest part of the open country whether occupied by trap or gneiss is covered with black soil. It has a great moisture

* International method.

holding capacity and in the rainy season, in certain parts is impassable. It is very deep and heavy. In the don valley the soils are very rich. On the banks of the Bhima and the Krishna also rich soils are found. Some of the black soils show presence of soluble salts and there are some which yield crops only with good and heavy rainfall. The red sandy soils found near the hills of Badami, etc., are generally poor. They yield only the rain crops and cannot hold moisture to allow any crop to grow after the rains.

In the Bagalkot taluka are found (1) deep black soils as at Govankop or Hungund (2) light soils as at Simikeri and Kamatgi and (3) sandy soils as at Badami and Guledgud. They are three distinct types as shown by the following figures. The variation is as shown by 4 to 6 samples of each group of soils:—

TABLE NO. 130.

Chemical Analysis.

—	Deep black soils.	Light soils.	Sandy soils.
	Per cent.	Per cent.	Per cent.
Loss on ignition ..	6.90 to 7.85	4.75 to 6.10	4.05 to 5.20
Silica and insoluble silicates ..	68.76 to 75.9	77.9 to 78.44	80.74 to 84.46
Iron and Alumina ..	8.30 to 10.20	10.50 to 14.50	7.40 to 9.50
Lime ..	2.97 to 5.59	0.45 to 1.85	0.16 to 1.23
Potash ..	0.12 to 0.23	0.25 to 0.42	0.31 to 0.39
Phosphoric acid ..	0.03 to 0.06	0.09 to 0.18	0.05 to 0.06
Nitrogen ..	0.03 to 0.04	0.09 to 0.12	0.05 to 0.08

TABLE NO. 131.

Mechanical Analysis.

—	Deep black soils.	Light soils.	Sandy soils.
	Per cent.	Per cent.	Per cent.
Clay and finest silt ..	32.0 to 40.0	10.0 to 16.0	13.0 to 15.0
Fine silt ..	7.0 to 15.0	10.0 to 28.0	12.0 to 19.0
Silt ..	2.0 to 6.0	7.0 to 20.0	3.0 to 10.0
Fine sand ..	8.1 to 10.3	15.8 to 23.0	7.8 to 22.7
Coarse sand ..	18.9 to 28.2	19.9 to 30.2	24.9 to 52.3

The distinctive characters of the three types are well shown by the above figures. The deep black soils are rich in lime fair to good in potash but practically poor in nitrogen and phosphoric acid. The light soils are fair to good in lime, rich in potash and good to rich in phosphoric acid and nitrogen. The sandy soils are fair to good in lime rich in potash and fair in nitrogen and phosphoric acid.

Some other typical soils of the District are given below :—

TABLE No. 132.

Chemical Analysis.

	Bagewadi garden soil.	Bagewadi Don valley soil.	Alluvial soil from Almari.	Soil from Mardi (light soil).	Mudde- bihal soil.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Loss on ignition..	9.54	8.60	7.42	6.54	2.86
Silica and insoluble silicates ..	60.29	63.21	64.87	67.61	89.57
Iron and Alumina ..	15.05	10.25	18.45	13.35	6.40
Lime ..	5.74	7.14	2.60	5.80	0.35
Potash ..	0.25	0.23	0.15	0.14	0.21
Phosphoric acid ..	0.19	0.18	0.12	0.19	0.09
Nitrogen ..	0.08	0.06	0.04	0.05	0.033

TABLE No. 133.

**Mechanical Analysis.*

	Bagewadi garden soil.	Bagewadi Don valley soil.	Alluvial soil from Almari.	Soil from Mardi light soil.	Mudde- bihal soil.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Clay and finest silt ..	34.0	34.0	22.5	13.0	14.6
Fine silt ..	22.0	17.0	19.0	24.0	3.5
Silt ..	11.0	13.0	25.0	31.0	3.0
Fine sand ..	10.0	11.6	23.8	26.0	12.9
Coarse sand ..	1.2	0.3	2.2	3.26	62.1

The Bagewadi soils are very retentive and well stocked with plant food constituents. They are rich in lime and good in potash, phosphoric acid and nitrogen. The lighter soils are poor in nitrogen and well drained and contain good proportions of plant foods. The Muddebihal soil is coarse and hungry.

* Done according to the International method.

APPENDIX.

Methods of Analysis.

Methods of analysis are modified from time to time and it is, therefore, necessary to indicate the processes which have been followed in obtaining the figures discussed in this bulletin.

Soils are analysed to determine chemical constituents, mechanical constituents and physical properties of the soils. The chemical analysis includes the percentage composition of the total quantities of the various constituents, percentage of available potash and phosphoric acid and soluble salts. The mechanical analysis gives the percentage composition of the particles of different sizes in the soil. The physical properties of the soils refer chiefly to the water-holding capacity, movement of water, etc., in the soils.

The methods adopted in analysing the soils discussed in this Bulletin are given below. Details are given only where short description of methods may not give a clear idea of the process followed. The soil which is received in the laboratory for analysis is spread out to dry and then pounded in a wooden mortar by a wooden pestle and passed through one millimeter sieve. The stones which remain above the sieve are weighed separately and the fine soil which passes through is taken for analysis.

I. (A) Chemical Analysis—

(1) *Moisture.*—About 5 grammes of the soil are put in a dish and dried in water oven. The temperature of the oven is at the boiling point of water. The soil is cooled and weighed. This is repeated till the weight becomes constant.

(2) *Loss on Ignition.*—The soil from which moisture has been determined is taken and heated first on a low flame and then ignited. It is then cooled and weighed. The loss in weight includes water not driven out at 100°C., organic matter and carbon dioxide from the carbonates. For preliminary examination the loss on ignition is taken to indicate roughly the proportion of organic matter in the soil.

(3) *Organic Matter.*—For accurate determination of organic matter ten grammes of soil are weighed in a conical flask and heated with dilute sulphuric acid to drive off carbon dioxide from the carbonates in the soil. The treated soil is then subjected to the oxidation process of potassium dichromate six grammes and 50 cc. sulphuric acid made up by mixing 30 cc. of strong sulphuric acid with 20 cc. of water. The mixture is heated in a paraffin bath kept on a low flame. The air which is drawn into the flask is deprived of its carbon dioxide by making it pass through a tube containing soda lime. The air from the flask, which is slowly drawn out by means of an aspirator, is passed first through a reversed condenser and calcium chloride tube to remove moisture, then through weighed caustic potash bulb where the carbon dioxide is retained and lastly through a weighed calcium chloride tube which retains any moisture that may be driven out from the caustic potash bulb by the bubbling

of the air. The increase in the total weight of the potash bulb and the last calcium chloride tube gives the weight of carbon dioxide produced by the oxidation of organic matter. An aspirator is attached at the end of the calcium chloride tube to draw air through the apparatus. The weight of carbon dioxide in grammes multiplied by 0.2727 gives carbon, but as carbon to the extent of $\frac{1}{4}$ th is not driven out it is further multiplied by 1.25. When the quantity of CO_2 is multiplied by 0.5877 it gives organic matter in the soil.

(1) *Total nitrogen* (excluding nitrite and nitrate nitrogen).—This is determined by the Kjeldahl's method. 10 grammes of soil are put in a Kjeldahl flask, wetted with water and then heated with 20 to 25 cc. of strong sulphuric acid. When the first fumes subside about 5 grammes of anhydrous potassium sulphate are added. The heating is continued till all the carbon is oxidised. The flask is then cooled. Water is added to it and the contents are transferred to a distilling flask (about 2,500 to 3,000 cc. capacity). Strong caustic soda solution is added to make the liquid in the distilling flask strongly alkaline. The ammonia evolved is driven out by passing steam and absorbed in a known quantity of $\frac{N}{10}$ sulphuric acid. The amount of sulphuric acid neutralised gives the amount of nitrogen in the soil.

(5) *Silica and Insoluble Silicates*.—For the determination of the inorganic constituents the ignited soil is heated in a dish with strong hydrochloric acid to dryness. This is done twice over and then extracted with dilute hydrochloric acid, filtered and the insoluble portion washed free of acid with hot water. The filtrate is collected in 250 cc. measuring flask. The insoluble portion is ignited and weighed as silica and insoluble silicates.

(6) *Iron and Alumina* (Fe_2O_3 and Al_2O_3): The filtrate from the above experiment is made up to 250 cc. Out of this 100 cc. are taken in a beaker and strong ammonia is added to make the solution alkaline. The iron and alumina and possibly some of the phosphates are precipitated. All these are collected together, ignited and weighed. The weight gives the amount of iron and alumina together (the phosphates form a negligible quantity). If iron is to be separately determined the iron alumina precipitate is dissolved in hydrochloric acid and the ferric iron is reduced by zinc to ferrous and titrated against $\frac{N}{10}$ potassium permanganate solution.

(7) *Lime* (CaO).—The filtrate which remains after the removal of iron and alumina is heated with dilute acetic acid and ammonium oxalate. The precipitate is ignited, treated with ammonium carbonate and the excess of ammonium carbonate is driven away by heating the precipitate. It is then cooled and weighed as calcium carbonate and calculated to CaO .

(8) *Magnesia* (MgO).—The filtrate from the above experiment is evaporated to dryness and ignited strongly to decompose all ammoniacal salts. The remaining portion is weighed and treated with hot water

and filtered. Magnesium remains on the filter paper as oxide while the chlorides of potassium and sodium go down into the filtrate. The total weight before hot water treatment contains magnesium oxide, potassium chloride and sodium chloride. The magnesia on the filter paper is ignited and weighed and the percentage calculated.

(9) *Potash* (K_2O).—The filtrate is evaporated down to a small volume. A little hydrochloric acid and enough platinum chloride are added to it and heated on a water bath. It is taken with 80 per cent. alcohol and filtered through weighed or counterpoised filter paper. It is weighed as potassium platinum chloride and calculated as potash (potassium oxide) per cent. on the soil.

(10) *Soda* (Na_2O).—This can be calculated from the weight of sodium chloride obtained by deducting the weight of magnesia and potassium chloride from the total weight of all the three.

(11) *Phosphoric Acid* (P_2O_5).—100 cc. from the stock solution obtained by treating the soil with strong hydrochloric acid is taken for the determination of phosphoric acid. It is precipitated by ammonium molybdate in the presence of ammonium nitrate and nitric acid. From the ammonium phosphomolybdate obtained phosphoric acid is calculated.

I. (B) *Available Potash and Phosphoric acid*.—Besides determining the total potash and phosphoric acid in the soil it is sometimes necessary to determine the percentage of available potash and phosphoric acid. This is done by what is known as Dyre's method. In this method 200 grammes of soil are shaken with 2,000 cc. of one per cent. citric acid solution for a week. It is then allowed to settle down and filtered. 1,000 cc. of the filtrate are evaporated to dryness and ignited to burn away all organic matter and the remaining portion extracted with hydrochloric acid, filtered and made up to a known volume. Half of this is used for the determination of potash and the remaining half for phosphoric acid by the methods already described. The results are calculated to percentage of available potash and phosphoric acid.

I. (C) *Soluble Salts*.—In the determination of soluble salts are included total soluble salts, sodium carbonate, total carbonates, total chlorides, sulphates, calcium and magnesium.

(1) *Total salts*.—100 grammes of soil are shaken with 500 cc. of water for quarter of an hour and filtered through a big Buckner funnel. 50 cc. of this are evaporated to dryness in a weighed dish on a water bath and then finally in a water oven. The dish is weighed till constant and salts calculated on 100 grammes.

(2) *Sodium carbonate*.—This is determined by titrating a suitable quantity of extract against $\frac{N}{20}$ $KHSO_4$ using phenolphthalein as the indicator. From the number of ccs. required the quantity of sodium carbonate is calculated.

(3) *Total carbonate*.—A suitable quantity of the soil extract is titrated against $\frac{N}{10}$ H_2SO_4 with methyl orange as the indicator.

(4) *Total chlorides*.—Suitable quantity of the soil extract is titrated against $\frac{N}{20}$ AgNO_3 with potassium chromate as the indicator.

(5) *Sulphates*.—50 cc. of the extract are taken for sulphate determination and precipitated with barium chloride or nitrate. The precipitate is weighed as barium sulphate from which sulphates are calculated.

(6) *Calcium*.—50 cc. of the soil extract are taken. Ammonium chloride and ammonia are added to precipitate iron and alumina. To the filtrate a few cc. of acetic acid and then ammonium oxalate solution are added to precipitate calcium oxalate. This is strongly heated, cooled and treated with ammonium carbonate and weighed as calcium carbonate. The calcium carbonate is then calculated to calcium oxide.

(7) *Magnesium*.—The filtrate from the above experiment is cooled. Ammonia and disodium hydrogen phosphate are added to precipitate magnesium as magnesium ammonium phosphate. This is then calculated to magnesium oxide.

There are two ways of expressing the results obtained from the determination of soluble salts. The results may be expressed in terms of ions such as CO_3 , SO_4 , Cl , Ca , Mg , Na &c. or may be expressed by the combination of the ions. When the latter method is adopted the procedure is as follows. The CO_3 necessary for sodium carbonate as determined by titration with potassium hydrogen sulphate with phenolphthalein as the indicator is deducted from the total CO_3 and is then combined with Ca . If CO_3 remains after combining with all the Ca it is given to Mg . If it still remains in excess it is combined with NaH to be calculated as sodium bicarbonate. CO_3 is many times not enough to combine with all Ca in which case excess of Ca is combined with SO_4 and then with Cl . If SO_4 after combining with all the available Ca remains it is combined with Mg and then with Na . Cl also is made first to combine with Ca if any is available after combination with CO_3 and SO_4 and then with Mg and finally all the remaining Cl is calculated as NaCl .

II. *Mechanical Analysis*.—International method of mechanical analysis is the one now-a-days followed in the Poona laboratory but formerly the old "Sedimentation method" of settling particles of soil in beakers was followed and that was the method used in determining figures in this Bulletin.

III. *Physical Properties*.—Physical properties of the soils are many and they are also very important in the study of the soils, but these were determined only in a few cases and hence these are not prominently mentioned in this Bulletin.

IV. *Bio-chemical Properties*.—In this presidency the bio-chemical study has not yet been taken up. In the case of the Kanara Cardamom cultivation, the soils were studied from a bio-chemical point of view

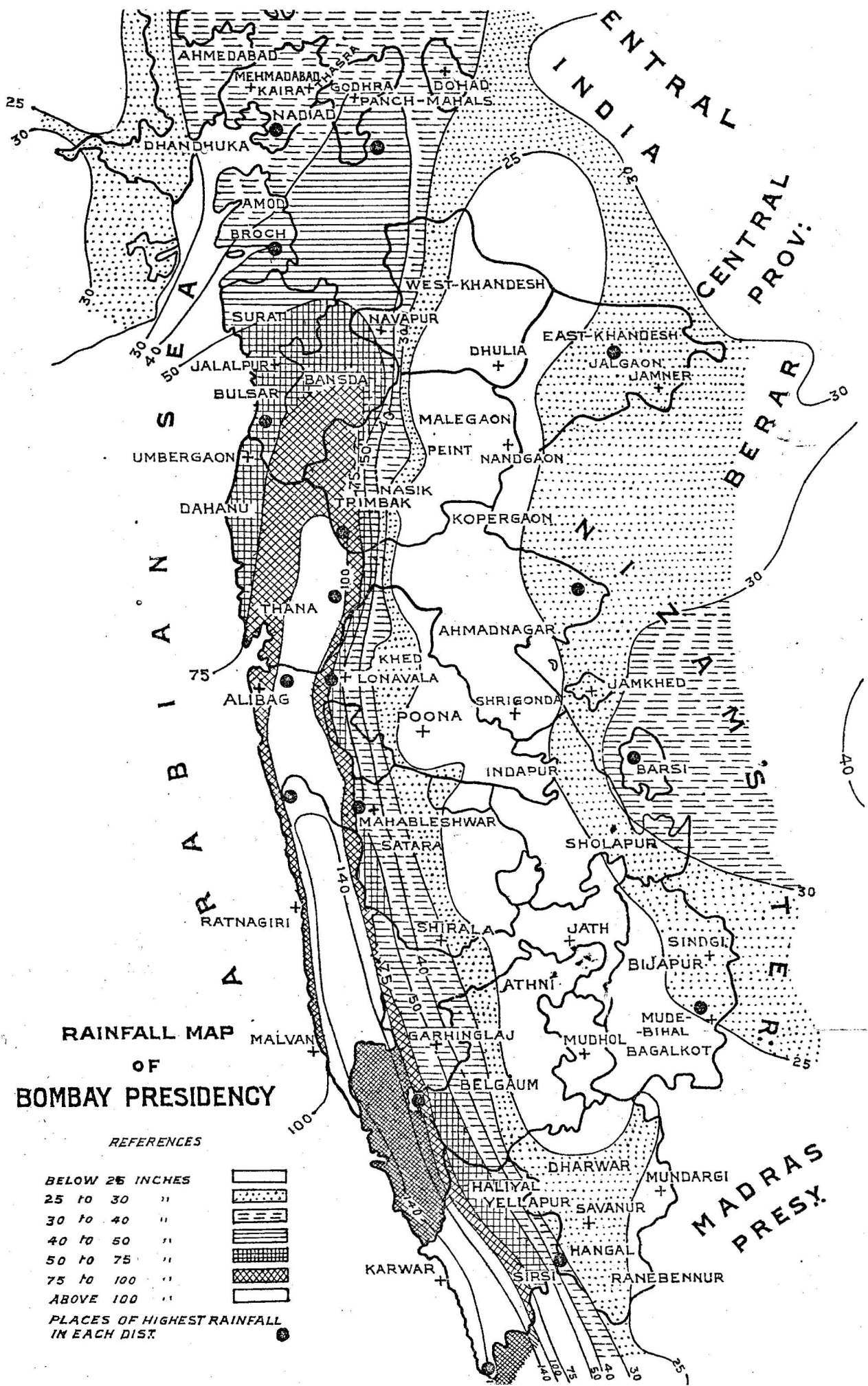
and the results have been published in a separate Bulletin (Bom. Ag. Dept. No. Bull. 157 of 1929). The methods used in that study are described in that Bulletin.

V. *The pH value.*—The pH value is determined by the colourimetric method or potentiometer. In the case of the soils given in this bulletin it was done by the colourimetric method. The results agree with those obtained with the potentiometer.

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**RAINFALL MAP
OF
BOMBAY PRESIDENCY**

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BELOW 25 INCHES	
25 to 30 "	
30 to 40 "	
40 to 50 "	
50 to 75 "	
75 to 100 "	
ABOVE 100 "	

PLACES OF HIGHEST RAINFALL IN EACH DIST.

GEOLOGICAL MAP
 OF THE
BOMBAY PRESIDENCY
 ADOPTED FROM THE MAP
 OF
 GEOLOGY OF INDIA.

SECOND EDITION

1891.

(Prepared by Geological Survey)
of India

Scale 1 Inch = 96 Miles

