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(*See inside of the back cover.*)

Pakistan Geographical Review

Volume 16 JANUARY, 1961 Number 1

RECLAMATION OF WATERLOGGED AND SALINE LANDS IN WEST PAKISTAN

3194

KAZI S. AHMAD

University of the Panjab, Lahore

AGRICULTURE plays a dominant role in the economy of West Pakistan, 63% of the working population is employed in agriculture, and there is a good percentage (10 -15)% which is partially or indirectly dependent on it. Excluding the sub-montane area in the north, the rainfall is generally deficient. More than 75% of the total cropped-area is irrigated, which rises to 100% in Sind and Baluchistan. Of the 28,860,900 acres of cropped area 17,549,100 acres or 60.8% are irrigated by canals. A great network of these exists in the Indus Plain, particularly between the Indus and the Sutlej in Punjab and along the Indus further below in Sind.

Appearance of Salinity and Waterlogging

The extension of canal irrigation during the present century brought large areas into cultivation leading to great prosperity of the country. But this boom did not last long. Percolation from canals greatly contributed to the rise of watertable in their neighbourhood and large areas of fertile land started developing salinity. Together with the appearance of salts on the surface or within the root zone of plants, many tracts of land also became waterlogged. Thus the water which brought life to large areas is now playing the reverse role, salinising and waterlogging them out of existence. The occurrence of salts in canal irrigated areas was noticed in some places as far back as the last quarter of the last century along with the rise of the sub-soil watertable, but it did not attract much attention, and, apart from some surveys lightly undertaken, nothing substantial was done for a long time. The menace has now reached an alarming stage and poses a great challenge to the country. In the Punjab region about 14% of the total canal irrigated area has gone out of production because of salinisation and another 17% of the canal irriagted area is in advanced stage of deterioration. Of the remaining lands in this region about 50% of the total is also affected although to a lesser degree. (10) It is estimated that 200 acres of canal irrigated land is going out of cultivation every day (9)

Twin Problems.—Salinity and waterlogging are twin problems. While salinity is the precursor of waterlogging, the two defects are in many parts found together, since high ground-water level contributes to the capillary rise of water to the surface, where it evapo-

A paper contributed to the International Geographical Congress symposium on agrarian geography held at Horsens Denmark July-August 1960.

rates leaving an accumulation of salt. In a hot and arid region like West Pakistan there is plenty of evaporation from the soil sucking the dissolved salts to the surface.

Apart from the percolation from the canals, the problem of salinity and waterlogging, has been aggravated, amongst other causes, by faulty irrigational and agricultural practices including insufficient water allowances, improper crop rotations, porosity of soil-cover and sub-terranean structure. The surface of the plain is extremely flat (with a gradient of 1 : 50,000). Rail, road and canal embankments obstruct surface drainage and the presence of clay lenses and sub-terranean barriers like the Delhi-Shahpur ridge, interfere with underground drainage. Where the soil-crust is thick (about 10′ or more) very little percolation takes place and sub-soil water cannot rise to the surface (1). Such soil is free from waterlogging but soil salts rise to the surface through capillary action. The problem has been aggravated by the silting up of the river beds and in some cases those of the canals. Under hydrostatic pressure, specially during the floods, large quantities of water are thus added to the ground-water.

Rise of Watcr table.—When the inflow of water from upper regions, by rainfall, floods, seepage from canals, spills from rivers and hill-torrents exceed the outflow to rivers, transpiration by plants and crops and the removal of water by drains, there is a rise in water table which fluctuates from season to season. If it comes to or near the surface it causes waterlogging.

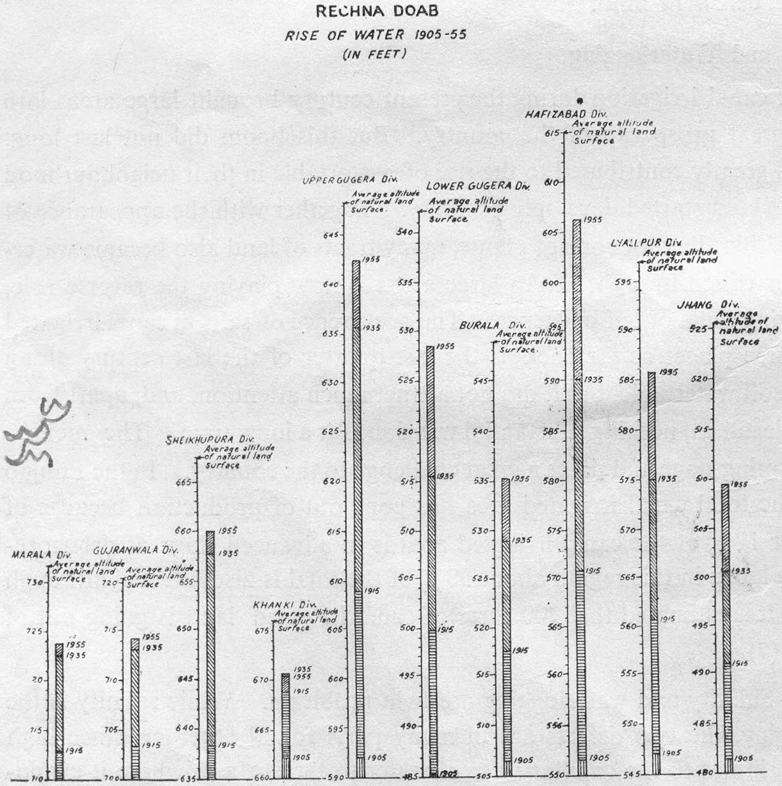

Fig. 1

The records of water table show that in pre-irrigation days water was generally deep, particularly in areas away from the rivers. In some parts the water table stood at 80-100 feet below the surface. Near the major rivers it was 5--15 ft. deep.

The water table has been rising during the present century by different amounts in various parts. The problem has become very acute in the Rechna Doab. It has been shown in Fig. 1. It will be seen that it has generally come to within 5-15 ft. of the surface. It is estimated by Nazir Ahmad (2) that in over 4.83 million acres or (50%) of the total area of Rechna and Chaj Doabs, water table lies within 10 ft. from the surface while in about 0.7 million acres it is within 5 ft. of it. Upward of the Delhi Shahpur sub-terranean ridge the water-table has approached the surface leading to waterlogging. The ridge, though not an effective barrier, does interfere with underground drainage. In the former Khairpur State, which is traversed by Rohri canal, 2 lakh acres of land are within 5 ft. hydro-isobath and 13,600 acres completely submerged under water. It has been estimated by the Ministry of Agriculture (16) that water-table is within 10-15 ft. of the surface in an area of 10.7 million acres. In 6.2 million acres of these the water table is within 8 to 10 ft. When this level is reached a direct relation is established between surface evaporation and underground water and dissolved salts are brought to the surface. Therefore the areas are badly effected by salts, where the water table has risen to within 8-10 ft. of the surface. Mehta (7) has shown that with soil-crust less than 6 ft. in thickness, and water table touching the bottom of this crust results in signs of waterlogging.

In the Bari Doab, ground-water generally lies at a depth that is out of the range of capillary action and water table is not much affected by percolation from canals. The sub-terranean-strata consist alternatively of clays and sands, and with a thick soil crust on top the conditions are such that percolation can have little effect on water table.

Patches of higher water table are distributed according to geological structure, depending upon the permeability and arrangement of the under-ground strata. The alluvial soils of the plains consist of alternate bands of horizontal strata, made of clay, sand or mixtures thereof in varying proportions. From the numerous well sections it has been seen that these bands are not continuous but they thin out and are replaced horizontally by others according to local conditions of deposition. The sequence of deposition may vary within short distances. Possibly many sheets of impermeable clay may have more or less basin from holding the water above. These clay lenses may also interfere with sub-terranean drainage.

Saline and Alkaline soils.—The soils of the Indus Plain consist of alluvium in which salts have accumulated in varying quantities in different parts according to local physical conditions during and since their formation, The saline type of soil locally known as Thur, is characterized generally by a high percentage of sodium salts and is fairly permeable to water. In winter white incrustation, consisting chiefly of sodium sulphate appears at the surface at many places.

The presence of sodium salts in the soil profile may bring a chemical reaction in the soil complex. High alkalinity may be developed and soil rendered unfit or lowly suitable for agricultural purposes. With alkalinity, the soil surface becomes hard, impervious to water and gives a metallic sound on tapping. The alkaline soil is locally known as *Rakkar*. In areas where the water table is high, in addition to high alkalinity, the soil profile exhibits a bed of calcium carbonate in the form of nodules beneath the surface layers. Sometimes the high alkalinity is due to free sodium carbonate, and the soil is infested with dark coloured patches found as a result of the dissolution of humus. It cannot produce even a blade of grass.

As regards the formation of these salts it may be pointed out in brief that the soils exposed to moisture, air and heat, are continually producing them. These constitute the bulk of the salts found in the soil crust. Besides all water, river, canal or under-ground, that has washed over or filtered through the ground, contains similar salts and promotes their further production to a certain extent. It has been estimated by Nazir Ahmad (2) that salts of the rivers of the Indus plain lie within 300 to 150 parts for every million parts of water. This percentage is very low and does not materially contribute directly to salinity. But these waters do help in the concentration of the salts already present by dissolving them.

Estimates of affected land.—Several estimates have been published about the area affected by salinity and waterlogging which greatly differ from one another.

(*i*) According to Lord Boyd Orr water and salinity had already affected 2.5 million acres. (Report of the Pakistan Agriculture Inquiry Committee, para. 138).

(*ii*) The National Planning Board has estimated that the area affected by salinity and rising water table by 1955 was 6 million acres of land to which 50,000 acres are being added annually. (First Five-Year Plan, Vol. II, p. 174, para. 59).

(*iii*) A report on "Progress of Economic development in Pakistan" issued in 1955 by the Government of Pakistan, shows that 500,000 acres in West Pakistan are waterlogged and about 2 million acres are suffering from salinity. These two menaces together have been putting out of cultivation annually from 30 to 40 thousand acres. (Progress of Economic development in Pakistan, p. 20, para. 81).

(*iv*) According to the Governor of the province, nearly half of the irrigated area had already been affected by waterlogging and salinity, and West Pakistan was losing about 75,000 acres of cultivable irrigated land every year. (Speech delivered on February 11, 1957 at Sind Agriculture College, Tando Jam).

(*v*) According to the latest estimates (April, 1958) by the Chairman, Soil Reclamation Board, 7 million acres were seriously affected and 12 million acres were partially affected in West Pakistan in a total area of 55.0 million acres of which 20 million acres were irrigated. (Report of the Economic appraisal Committee p. 60, para. 183).

(*vi*) S. I. Mahboob, Chief Engineer (West Pakistan Engineering Congress, 44th General Meeting, Lahore, February, 1960), Irrigation West Pakistan has estimated that in the former Punjab in which the total canal irrigated area is about 13.3 million acres, about 3 million acres are seriously affected by salinity, of which 1.3 million acres have completely gone out of cultivation. In addition, the area in which salts have appeared on more than 20% of the surface, and have thus appreciably reduced productivity, is about 5 million acres. The estimate for the area severely affected in the whole of West Pakistan is 7 million acres. In the former Punjab, we are losing about 70,000 acres per year due to salinity whereas the figure for the whole of West Pakistan is estimated at about 100,000 acres. In other words, this sore is spreading at the alarming rate of over ten acres per hour, day in and day out, throughout the year.

More accurate detailed statistics for the Indus Plain region have recently become available on the publication of the report by the Canadian Photographic Survey Corporation, Toronto. They are given in Table I.

TABLE I

INDUS PLAINS : SALINITY AND WATERLOGGING ACCORDING TO REGIONAL DIVISIONS

Region	Mapped as Predominantly Poorly Drained or Waterlogged		Mapped as Predominantly Severely Saline		Area in which Saline Patches are Common*	
	Square miles	Per cent. of region affected	Square miles	Per cent. of region affected	Square miles	Per cent. of region affected
Peshawar Vale	251	11.5	..	..	113	5.0
Bannu Basin	..	..	..	..	..	
Sulaiman Piedmont	571	7.5	..	..	111	1.5
Kachhi Plain	163	2.5	127	2.0	..	..
Kirthar Piedmont	140	11.5	12	1.0	..	..
Karachi Plain	..	..	12	1.5	..	..
Potwar Uplands	..	..	..	..	..	..
Salt Range and Salt Range Piedmont	..	..	109	2.5	..	..
Himalayan Piedmont	..	..	..	..	..	..
Sind Sagar Doab	803	8.0	290	3.0	701	7.0
Cnaj Doab	1,010	23.0	272	6.0	889	20.0
Rechna Doab	4,232	35.5	1,770	15.0	3,598	30.5
Bari Doab	55	.5	164	1.5	920	7.5
Bahawalpur Plain	779	13.0	..	..	244	4.0
Indus Flood Plain	..	..	62	1.0	40	.5
Indus Corridor	81	1.5	154	3.0	2,942	62.0
Upper Sind Plain	5,137	98.0	1,691	32.5	3,385	64.5
Central Sind Plain	1,609	14.0	343	3.0	2,991	25.5
Lower Sind Plain	2,890	93.5	1,548	50.0	1,342	43.5
Indus Delta	1,062	27.0	1,298	33.0	416	10.5
INDUS PLAINS	18,783	17.0	7,852	7.0	17,692	16.0

*Does not include areas tabulated in column "Mapped as Predominantly Severely Saline".

Saline Lands.—The distribution of predominantly severely saline lands and areas in which saline patches are common is shown in Fig 2. These represent uncultivated land covered with salt and efflorescence in winter and thus show the efflorescence when it is most extensive. In some places salts are washed by means of irrigation in summer but return to the surface in winter. These seasonal changes could not be indicated on the map. It will be seen that predominantly severely saline lands are found in, (*i*) upper middle part of Rechna Doab, together with an adjacent small tract in the N. E. part of the Bari Doab and a small area in the N. E. Part of the Chaj Doab, (*ii*) Upper Sind Plain, west of the Indus

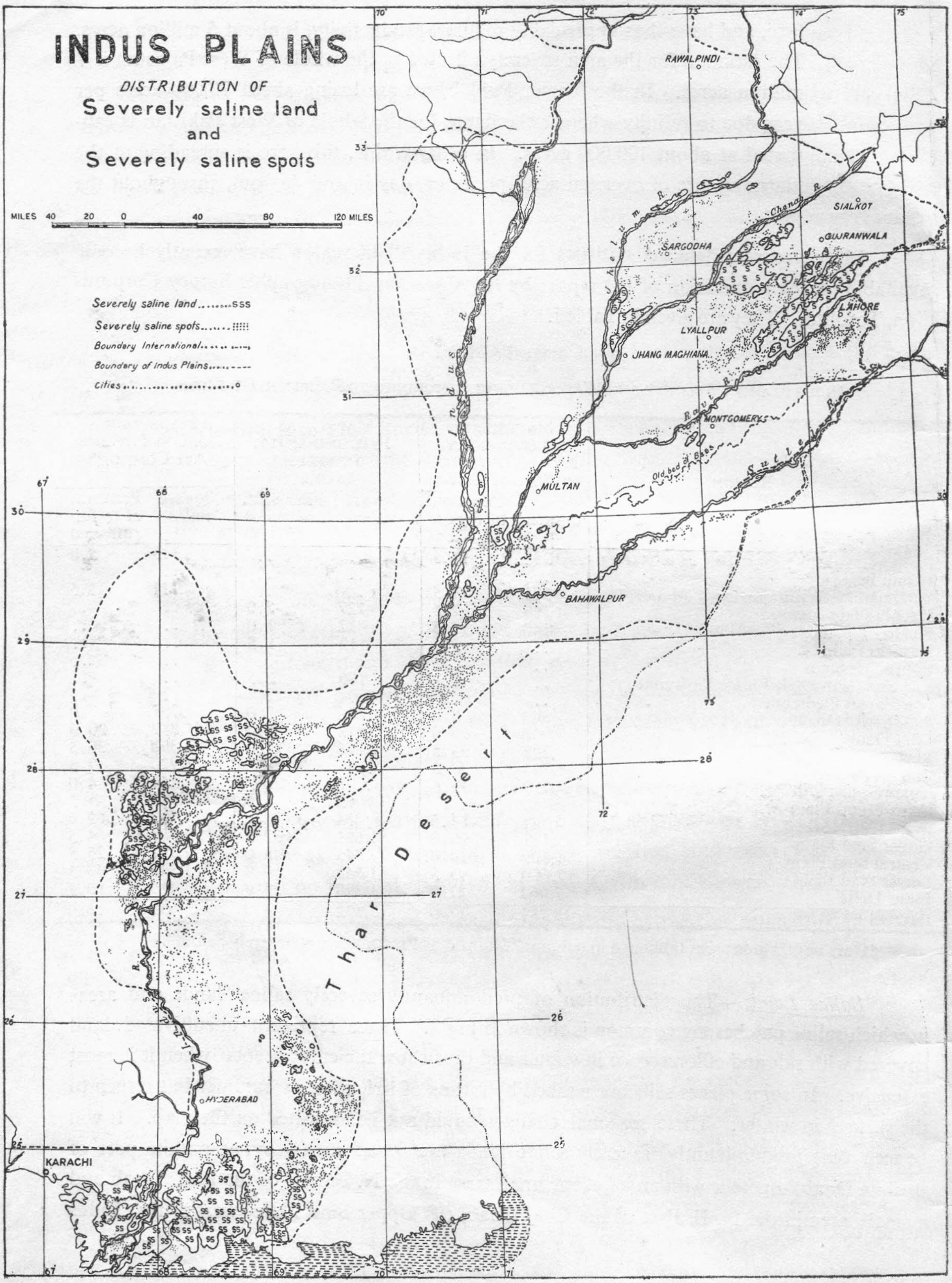
INDUS PLAINS
DISTRIBUTION OF
Severely saline land
and
Severely saline spots
MILES 40 20 0 40 80 120 MILES
Severely saline land ....SSS
Severely saline spots.......
Boundary International.......
Boundary of Indus Plains.......
Cities.........
RAWALPINDI
SIALKOT
GUJRANWALA
SARGODHA
LAHORE
LYALLPUR
JHANG MAGHIANA
MONTGOMERY
MULTAN
BAHAWALPUR
HYDERABAD
KARACHI
Jhelum R.
Chenab R.
Ravi R.
Sutlej R.
Indus R.
Old bed of Beas
Thar Desert

Fig. 2

and (*iii*) Lower Sind Plain south of Hyderabad and Indus delta. There is a fourth area, but smaller in size, in the south Chaj doab, where the Chenab and the Jhelum come closer together. There are two smaller severely salt-affected areas, (*i*) along the Jhelum in the Piedmont of the Salt Range and (*ii*) in the Kachhi plain. Apart from the upper Rechna Doab, saline patches are common from near about Muzaffargarh, Lat. 30°, south-ward along the canal irrigated area on the east bank of the Indus up to the end of the canal-irrigated area in the district of Tharparkar.

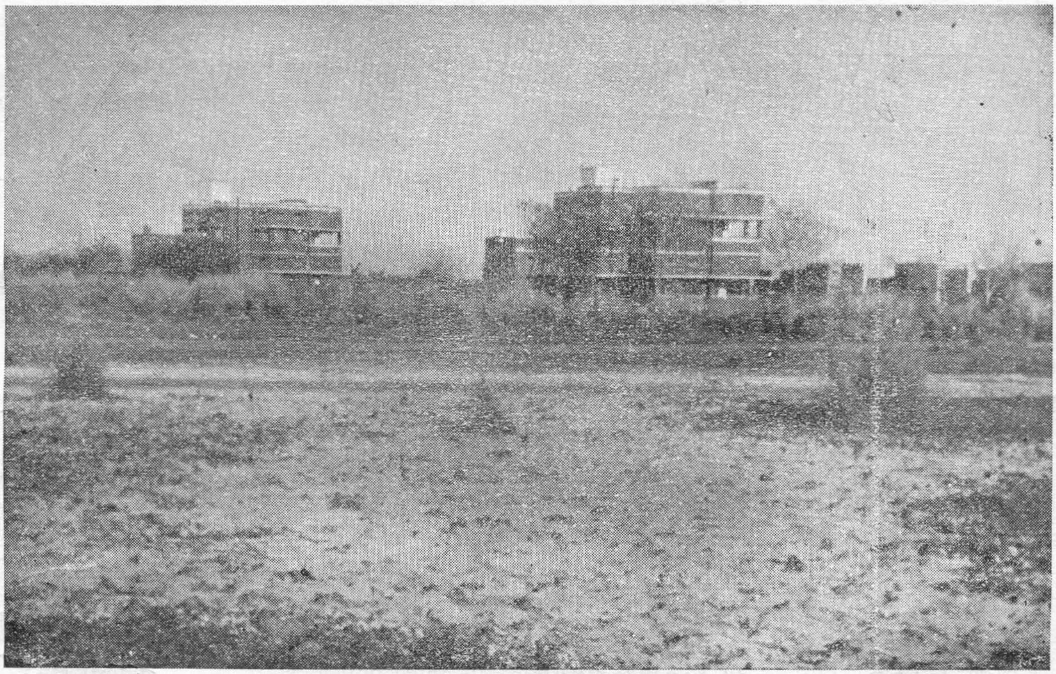

Fig. 3. Salt efflorescence in Jauharabad (Thal)

The sub-montane tract is free both from salinity and waterlogging. The rainfall here is sufficient to scour the surface. As the soil is permeable on account of the presence of gravel and sand and the land has a good slope, the surface and sub-soil drainage is quite efficient. Similarly the Sulaiman and Kirthar piedmonts are little affected by salinity and waterlogging. They are found only near their lower edges.

The active flood plains of the rivers (or *bet*), which are flooded at least once during the monsoons, are free from salts on account of the thorough flushing that the land receives. There are no salts even beneath them. The water percolating from the rivers forms a sub-terranean stream gravitating down the river-course and accompanying the main stream. The meander flood plain adjacent to it and cover flood plain still further from it, built by sheet flooding, are generally the areas which have present or potential salinity and water-logging problems. In still higher central part of the interfluves (or *bar*) these problems do not exist in many areas where sub-soil water table is not high.

The extent of land affected by salinity in various regions of the Indus plain is shown in Fig 4. The percentage of predominantly severely affected land is highest in the upper Sind plain (32.5%), lower Sind plain (50%) and the delta (33%). In addition 64.5%, 43.3 and 10.5 per cent of these regions respectively are covered with saline patches. About two thirds (64%) of the land along the east bank of the Indus, between Mithankot and Sukkur, is covered with saline patches. Here the Thar desert comes very close to the river. In the Punjab the percentage of saline lands is highest in the Rechna Doab.

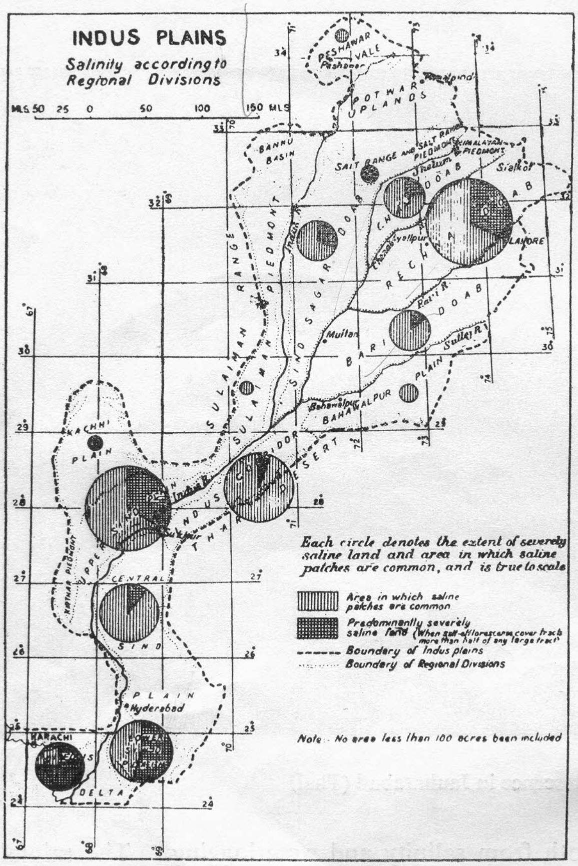

Fig. 4

Waterlogged areas.—Regional distribution of waterlogged areas is shown in Fig. 5. It includes areas in which ground-water lies at or near the surface even in winter, so that it precludes or lessens crop yields for at least a part of the year. Although waterlogging is comparatively less wide-spread than salinity, its regional distribution well corresponds with the saline areas and the conclusion is drawn that it has contributed to the extension of salinity in them. Waterlogged and poorly drained areas chiefly occur—(*i*) in the upper middle parts of Rechna and Chaj Doabs, up-stream of Delhi-Shahpur sub-terranean ridge, (*ii*) southern tips of the doabs where the rivers meet, (*iii*) along the southern bank of the Sutlej in Bahawalpur, (*iv*) in the upper Sind plain, (*v*) in the lower Indus plain and the delta, under hydrostatic pressure from raised river-bed, in an absolutely flat land and (*vi*) in the S. Eastern irrigated part of the central Sind plain, with a highly porous soil. The conspicuous areas where salinity occurs without waterlogging are the Salt Range and Salt Range piedmont. Again in the Indus valley between Mithankot and Sukkur, where the Thar desert comes close to the river, salinity is much more extensive than waterlogging.

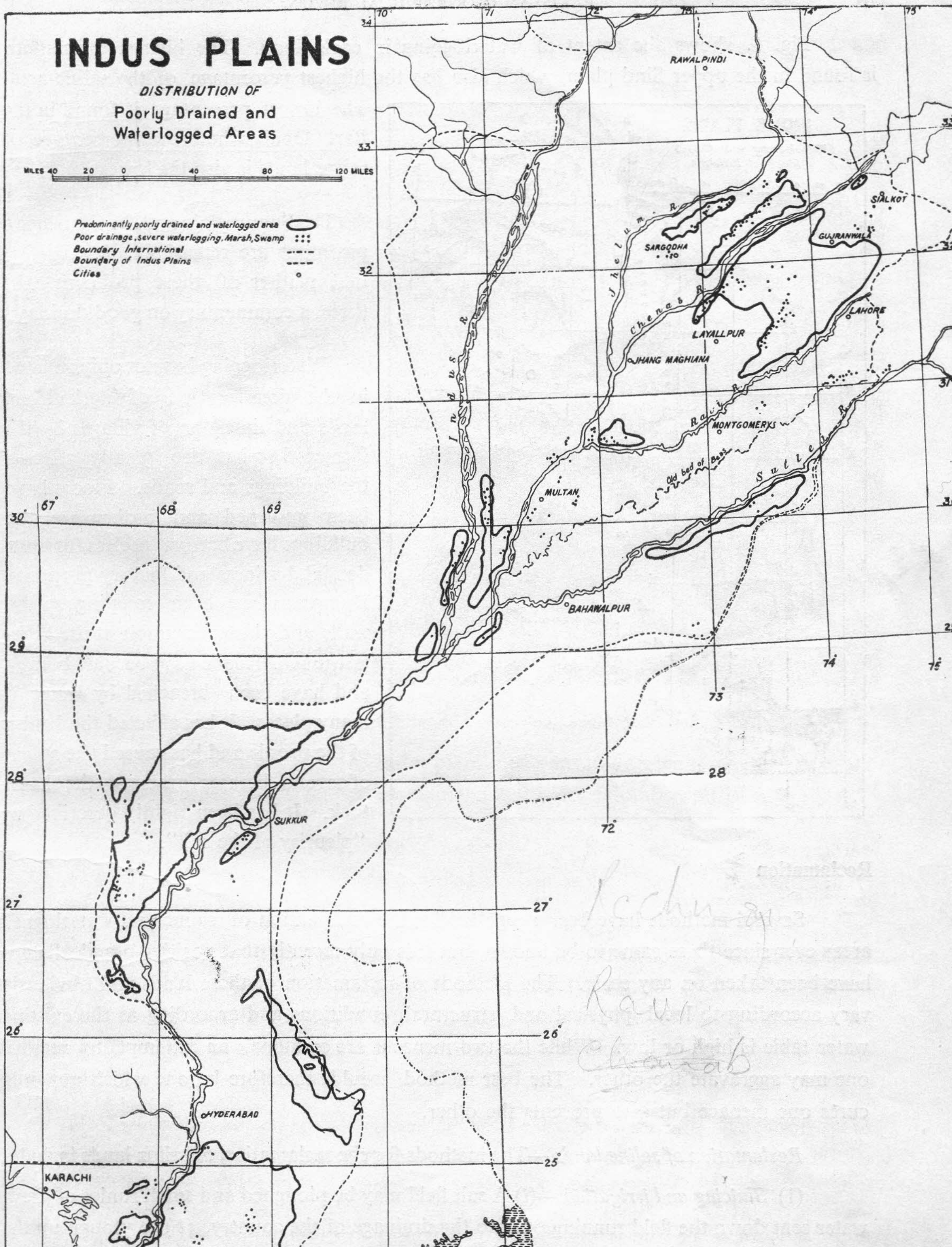
INDUS PLAINS
DISTRIBUTION OF
Poorly Drained and
Waterlogged Areas
MILES 40 20 0 40 80 120 MILES
Predominantly poorly drained and waterlogged area
Poor drainage, severe waterlogging, Marsh, Swamp
Boundary International
Boundary of Indus Plains
Cities
RAWALPINDI
SIALKOT
GUJRANWALA
SARGODHA
LAHORE
LAYALLPUR
JHANG MAGHIANA
MONTGOMERY
MULTAN
BAHAWALPUR
SUKKUR
HYDERABAD
KARACHI
Indus R.
Jhelum R.
Chenab R.
Ravi R.
Sutlej R.
Old bed of Beas

Fig. 5

Fig. 6. shows the extent of waterlogging in each doab. The highest percentage is found in the upper Sind plain, which also has the highest percentage of the saline area. The lowest percentage is found in the Bari Doab where the percentage of saline lands is also the lowest.

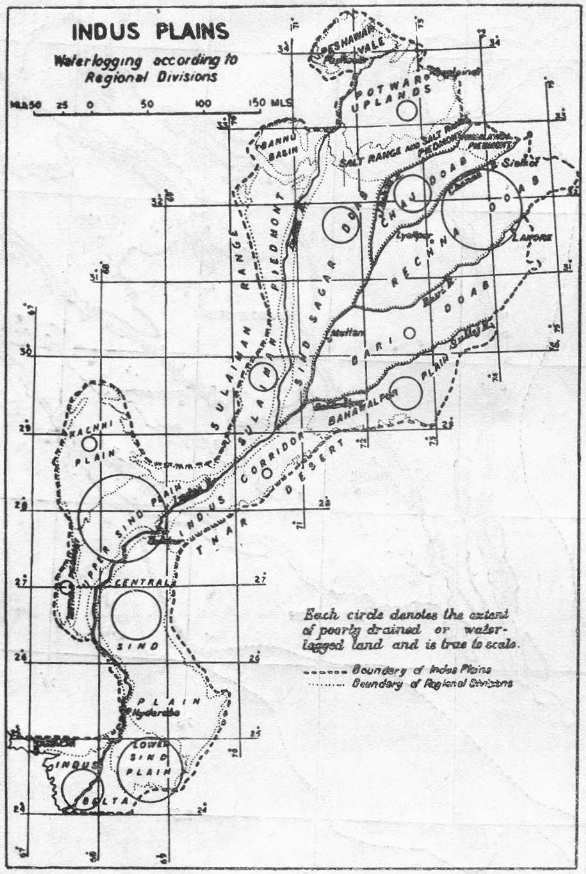

Fig. 6

The Bannu plain and the Himalayan piedmont are remarkable for the fact that neither of these problems exist there, a commentary on good drainage.

Waterlogging has not only resulted in the deterioration of agricultural lands and desertion of villages by the farmers but has also greatly affected the buildings and roads. Floors have been upturned and broken and the buildings have become useless for residential, business and factory purposes. Dampness has been creeping up the walls and plasters crumble at the slightest touch. Roads have become bumpy and have been breached by water at many places. It has affected the health of the people and has caused the spread of several diseases amongst the livestock. It has been rightly described as "pleurisy of the soil".

Reclamation

Several methods have been suggested for the reclamation of saline and waterlogged areas ever since these came to be known, but it is only recently that positive practical steps have been taken on any scale. The methods of reclamation of these lands will obviously vary according to local physical and structural conditions and according as the existing water table is high or low. While the two menaces are so allied, an attempt to remove one may aggravate the other. The best method would therefore be one which not only cures one menace but also prevents the other.

Reclamation of saline lands.—The methods for the reclamation of saline lands include:

(1) *Sluicing and irrigation.*—(*i*) A salt field may be ploughed and small runlet of fresh water sent down the field running off into the drainage of the country, (*ii*) to plough up the field and make a terrace around it and then flood it. The water is allowed to soak for some

time till it has dissolved the salt and it is then run off, (*iii*) to terrace a ploughed field and dig a deep trench.

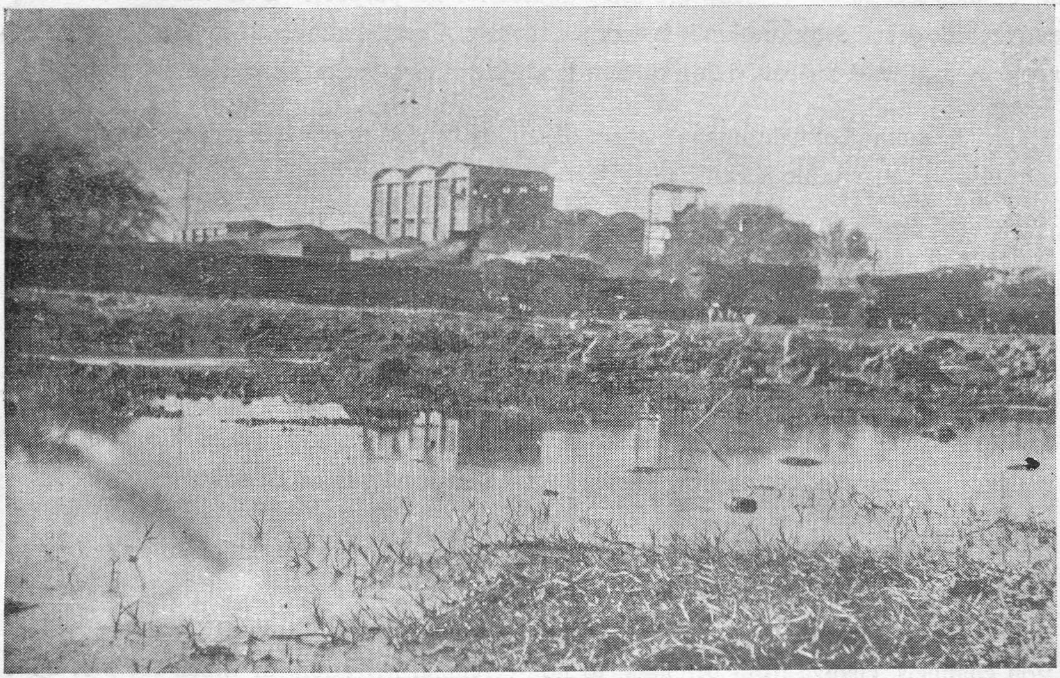

Fig. 7. A Patch of waterlogged land in front of Koh-i-Noor Sugar Mills Jauharabad (Thal)

In a flat country like that of the Indus plain where natural drainage may not be available, it may be possible to run off the salt impregnated water into absorption wells.

(2) *Chemical manures.*—By the use of nitrate of lime as a manure. Such a manure of good quality could be made by mixing pounded *Kankar* or marly soil with animal manure and moistening it frequently during one or two hot seasons.

(3) *Arboriculture.*—The plantation of trees is also proved to be an efficient means of curing salinity. *Kikar* (Acacia arabia) is capable of flourishing in such soils. These absorb and remove certain amount of salts from the soils. As the salts exist chiefly in the surface soils and in much less amount at a small depth, trees may grow readily while crops could not.

(4) *Through planned cropping.*—Cropping may facilitate the leaching while roots make the soil more permeable. A crop like rice is chosen which is adaptable to wet conditions and tolerant to salt. The salts are flushed out of the root zone.

The method of reclamation of saline soils in Rechna and Chaj Doabs, which is being practised for several years, is the leaching of salts by flooding and growing paddy during summer, followed by a winter legume grown mainly on residual soil moisture. This is done for two or three years after which the land becomes fit for normal production. At present about 4000 second feet of water are being utilised for the purpose. Even this is inadequate and the rate of soil deterioration is faster than the rate of reclamation. It implies more water not only to extend the cultivation on new lands but also to reclaim the salt-affected lands.

The method of fighting the menace of salinity by rice-cropping is successful only when the sub-soil water table is sufficiently deep to permit the leaching of salts below the root zone. Where the water table is high, nothing but drainage can help, and for effective drainage of salts more water is needed.

Salinity may also be prevented to a certain extent by adopting crop rotations which reduce the extent of fallow or idle land, the presence of which promotes evaporation and movement of salt to the surface. Salt-resisting varieties of crops may be imported from countries like Algeria or Soviet Russia and introduced on a large scale. Some of these varieties like those of cotton have shown even better results in saline soils.

Prevention and reclamation of waterlogged areas.—For the prevention of waterlogging and reclamation of waterlogged areas, various methods have been tried, including canal-lining tube-well pumping, open drains, canal closures, lowering of full-supply level of irrigation channels, change from perennial to non-perennial irrigation, of which the first three have been more important.

Heavy seepage from canals is considered to be one of the principal causes of waterlogging. However, where the surface soil is impermeable or where there is more than 5 ft. of clay-soil below the bed of the canal, practically no seepage takes place. In areas where the canal has cut through the soil-crust and the bed is in sand, seepage is heavy. Stopping the heavy percolation from the canals by lining is considered to be the most effective and permanent remedy. But it involves heavy expenditure and closure of canals for long periods. It is difficult to line the old canals, and there has been no suitable cheap material available for the purpose. The only effective canal linings, known till the time of the independence, were of cement and brick and cement-concrete. Thirty miles of Thal canal have been lined with cement mortar and the rest with brick tiles. Experiments have been made with other materials but are not recommended. In the United States the Bureau of Reclamation have developed a method of lining the canals with Bentonite. This method appears to suit our conditions. Besides being cheap it may not require closure of the canals. Bentonite can be pounded into fine particles. It is available in some parts of Panjab and Azad Kashmir. Alternatively to it, injection of bentonite, mud-jelly or a mixture of cement and mud into the soil 5 or 6 ft. below the porous bed of canal has been considered to be effective for the purpose.

It may, however, be pointed out that percolation "from canals" contributes to the building up of under-ground resources of water. The emphasis should not be on preventing the percolation of water but on disposing it of before it rises to a dangerous level.

To reduce the canal-seepage component of ground-water recharge, periodic canal closures have generally been abandoned as an anti-waterlogging measure, on account of disruption that it causes in cultivation.

Tubewells for drawing water from below the soil-crust have been considered to be an effective method for lowering the water table as anti-waterlogging and anti-salinity measures. An additional advantage is that the water pumped out, if not saline, may be used for irrigation. A big tubewell project involving about 1500 tube-wells generally known as Rasul Tube-well Scheme, was started in Punjab before the independence, and has since been completed. The water in some cases has been brackish and it has been difficult to dispose it off. In other cases pumping increased seepage flow from the big canals closely. This method is, however, being preferred both as a means of reclamation and irrigation. In 1958, the Government approved another plan for the construction of 1800 tube-wells for the reclamation of lands affected by waterlogging or salinity in various parts of West Pakistan over a period of three years. Construction was started by the Irrigation Department in September, 1958 and the project was transferred to WAPDA in March, 1959. Tube-wells are being constructed for the drainage of soil profile through pumping and to provide additional irrigation water. A limiting factor is the availability of cheap hydel power.

The Government of Pakistan have inivited a number of foreign experts during recent years to advise them on the reclamation of waterlogged areas. As a result of their recommendation the Chuharkana Reclamation Scheme (District Sheikhupura) has been in operation since 1953. In this experiment it is intended to lift the sub-soil water by tube-well and use it on the same land for raising crops. It is thought that the level of sub-soil water will sink to a sufficient depth to permit healthy plant growth.

It has been argued by some that deep tube-wells presently in use drawing water from about 200 ft. may be useful for providing water for irrigation and the leaching of salt, but shallow tube-wells (about 50-100ft.) may be more effective to fight waterlogging as they will draw water from the affected area near the surface. If the water is found to be brackish it could be diluted with fresh water for irrigation purposes. For the same reason it is suggested that building of surface percolation wells may be encouraged in suitable areas. They are less expensive to construct with close spacing may collectively produce good results. Asghar has shown that water available in high water table areas is of good quality and could be used for irrigation directly or by mixing with canal water. (3)

It has been observed that in areas, where the water table is near the land surface, the chemical quality of the ground-water is such that the waters can be used for irrigation with or without dilution with canal water. Such areas lie generally north and east of the Shahpur-

Delhi Ridge through Rechna Doab (10). In Chaj Doab water is however chemically different from that of the Rechna Doab. The quality of water near Bhalwal and Sargodha is generally unsuitable for irrigation use. (10)

With the rise in water table, in any scheme of reclamation, the need for providing artificial drains for the disposal of surface and seepage water is apparent. An efficient system of surface drainage would prevent waterlogging and keep it in control but the flatness of the country is a limiting factor. The first experiment was carried out at Chakanwali Reclamation Farm (District Gujranwala) where an attempt was made to drain water from the soil. It was found that for successful operation the drains have to be kept clean. This is not always possible if an extensive system of drains is to be laid out.

The Irrigation Department dug 2263 miles of drains which, however, do not seem to have worked satisfactorily. Their main use has been to carry away surplus rain water. The surface drains tried so far have inadequate out-falls and insufficient bed slopes. It may be necessary to install pumping plants at the out-falls as is done in Egypt and Holland.

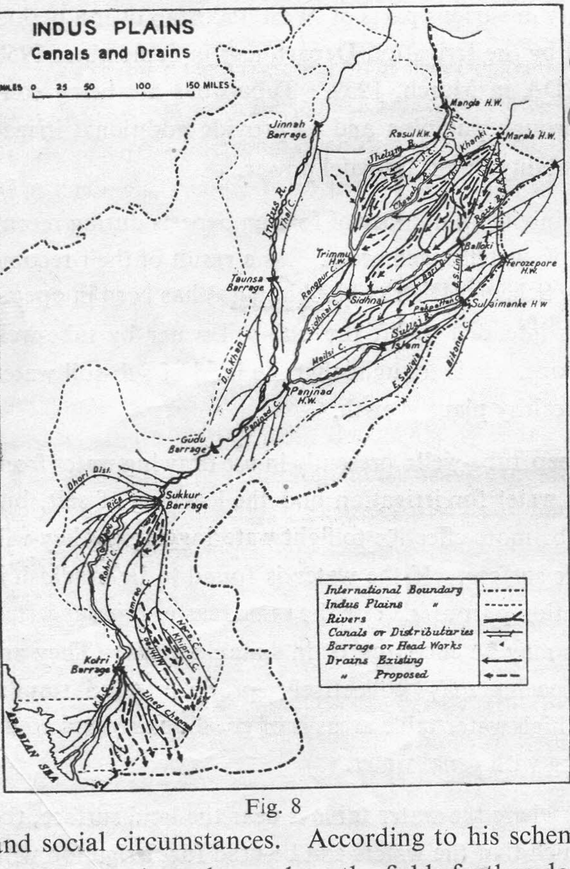

Fig. 8

The drains constructed and proposed in Indus Plains are shown in Fig. 8. Apart from the construction by the Government, the landlords and farmers are being encouraged to dig small drains which will have connection with large drains, which will take the water to the sea.

In the sub-montane areas the *nullah* and hill streams serve as natural drains. Similarly spill channels which emerge from the rivers and rejoin it lower down (called Budhs) serve as natural drains for the riverain area.

Dr. Vlugter, an expert of the Netherlands Bureau of International Technical Assistance on Drainage and Reclamation has recently expressed his conviction that a combined irrigation-drainage system would work out well under our meteorological, agricultural and social circumstances. According to his scheme seepage water will flow through nearby drains and can be used on the fields further down stream.

Brief History of Reclamation.—Waterlogging has been recognized as an evil in Punjab since 1841, but little practical progress has been made towards its prevention or its cure. The problem of salinity and waterlogging first attracted the notice of the Punjab Government in 1908 where an Executive Engineer was deputed for the investigation of the area waterlogged in the region of the Upper Bari Doab Canal. As a result of experiments some tube-wells were sunk. Waterlogging problem came to the fore-front in 1915-16, posing a great threat to the prosperity of the province. A Drainage Board was set up in 1917 in order to investigate the causes and effects of waterlogging and suggest suitable remedies for a successful attack on the problem.

In 1925 the Drainage Board was split up into Waterlogging Enquiry Committee and the Rural Salinity Board. The same year an Irrigation Research Laboratory (now Irrigation Research Institute) was established in the Irrigation Branch.

In 1928 in order further to intensify reclamation efforts a Land Reclamation Board was set up which, like previous organizations was also an advisory body.

A separate Land Reclamation Directorate was opened in 1945 under the control of Irrigation Branch with a view to expanding and intensifying reclamation activities.

As a result of the efforts of the Directorate of Recalmation about 20,000 acres of land were annually reclaimed in Punjab but actually more land was going out of cultivation than reclaimed by the Directorate.

In 1952, the Punjab Soil Reclamation Act was passed under which a Statutory Soil Reclamation Board was established to undertake reclamation work along broader lines in larger areas under a long term programme. It was vested with great powers covering all measures in the field of water-supply, agriculture, afforestation marketing, loans of cash equipment, etc.

The activities of the Irrigation Department have been consisting of remedial work in isolated areas affected by salinity. Several hydel projects were made to utilise low head falls on the canals, for providing cheap hydro-electric power to operate primarily a net-work of tube-wells for pumping out water and keeping the sub-soil water low in areas affected by waterlogging and salinity.

In May, 1954, Ground Water Development Organization was set up by the Government with the co-operation of U. S. A. to undertake an investigation of the ground-water resources of the former Punjab areas for use in the planning of further irrigation, drainage and land reclamation.

To determine the causes responsible for the growth of salinity and waterlogging and devise suitable measures for their control at an economic and justifiable cost, investigations, were initiated over a greater part of the badly affected areas of the former Punjab towards the latter part of 1954. These investigations have almost been completed in Rechna and Chaj Doabs and are in various stages of completion in Thal area and former Bahawalpur state. Water and Power Development Authority (WAPDA) was established in February, 1958 to provide for the unified and coordinated development of water and power resources of West Pakistan. It has also been entrusted with the installation of tube-wells for the prevention of waterlogging and reclamation of waterlogged and saline lands. In April, 1960, Ground Water Development Organization has also been put under it.

Progress of Reclamation.—The progress of reclamation operations in the former province of Punjab, to which the work has been confined so far is given in Table II. It shows that in a period of 19 years only 0.37 million acres could be reclaimed. The annual average area reclaimed works out to be 18,686 acres since 1939 and only 2353 acres since independence. If the annual affected area is taken to be about 70,000 acres it means that reclamation operations cover only about one-third of the affected area.

TABLE II

PROGRESS OF RECLAMATION OPERATIONS IN THE FORMER PUNJAB

Year			Area Reclaimed during the year†	Progressive Total
1939-45*	..	..	62,921	62,921
1945-46	..	..	23,085	86,007
1946-47	..	..	28,913	114,920
1947-48	..	..	29,336	144,256
1948-49	..	..	24,165	168,421
1949-50	..	..	17,110	185,531
1950-51	..	..	22,190	207,721
1951-52	..	..	17,399	225,120
1952-53	..	..	12,907	238,027
1953-54	..	..	26,810	264,837
1954-55	..	..	26,240	291,077
1955-56	..	..	36,782	327,859
1956-57	..	..	19,921	347,780
1957-58	..	..	25,973	373,753

*Yearwise figures not available. †Figures in Acres.

Current operations.—Although the progress of reclamation has been very slow so far, the food shortage in the country during recent years has focussed attention not only for the increase in the cultivated area and the crop yields but also on the reclamation of fertile lands lost through salinity and waterlogging. At present these operations are mainly the concern of WAPDA. It prepared a Salinity Control and Reclamation Project in January 1959 to reclaim 1.4 million acres of waterlogged and saline lands by June, 1961. The project is the first phase of the reclamation programme and aims at the installation of 1888 tube-wells of different capacities in 1.37 million acres of land of Rechna Doab and 159 wells in 0.2 million acres of the Chaj Doab in the districts of Gujranwala, Sheikhupura and Lyallpur. It includes the reclamation schemes of Chuharkana (Sheikhupura), Zafarwal (Sheikhupura) Harse Sheikh (Jhang), Beranwala (Lyallpur), Hafizabad (Gujranwala) Shadman and

Sangla Hill (Sheikhupura) in Rechna Doab and Lalian (Jhang) in Chaj Doab. Of these the 1st four are being executed by the Soil Reclamation Board and the rest by WAPDA. The project is intended to serve both purposes. It will provide additional irrigation supplies, through pumping from the ground-water reservoir and will also in the same process provide for the drainage of the soil profile. The reclamation is estimated to be at the rate of over 500 acres a day. On the completion of the proposed programme it is expected that food production will rise by 0.7 million tons during the 3rd year of the operation and by 0.8 million tons during the 5th year of the operation. There will be a substantial increase in the production of cotton and sugarcane, the two important cash crops of the region. The cultivator's income per acre per year will increase 4 times within 5 years and the food grain produce from the area will be about doubled.

The completion of the project, feasible in itself, is linked with the simultaneous completion of two other projects. (*i*) The West Pakistan High Tension Grid which will link up the several electricity production centres in the north-west Pakistan and (*ii*) The Pakistan Secondary Transmission Project which through a net-work of transmission lines, will provide link between the centres and the consumers—including the running of tube-wells for agriculture.

According to the rural electrification programme about 300 villages will be connected by June, 1960 and at least 1000 villages a year will be connected for the next 5 years.

Realizing the grave situation in West Pakistan WAPDA has now with the help of Hunting Technical Service started investigations into waterlogging and salinity in the Sukkur-Gudu and Ghulam Muhammad Barrage and Khairpur areas. These investigations will extend over more than 10 million acres of irrigated lands in the southern region. According to the programme WAPDA is to prepare a comprehensive drainage and salinity control plan for the areas and execute the necessary drainage system—the drainage at a rate to cover one million acres a year.

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GLACIERS OF NANGAPARBAT

F. LOEWE

University of Melbourne, Asutralia

GLACIERS cover a considerable part of the mountain ranges of Pakistan, the Himaalayas, the Karakoram and the Hindukush. Twenty five percent of the surface of the Karakoram is glacierised. Glaciers are of very great economic importance because in the arid parts of northern Pakistan the melting of glacier ice provides much of the irrigation water upon which life in these regions depends. Just at the time of greatest water need in summer the supply of meltwater is most plentiful. In contrast to this regular beneficial effect glaciers have often acted in a destructive way, by overrunning of fields and buildings (6) as in the case of the Kutiah Glacier in Baltistan (2) of the Yangutz Har Glacier in Nagar (6, 12) or by the blocking of rivers, the creation of temporary lakes and the sudden release of enormous amounts of water as the Chong Kumdun Glacier in eastern Ladakh (12) or recently glaciers in the Shimshal valley of Hunza (5).

The best known ones among the glaciers of Pakistan are those of the Nanga Parbat group. Until quite recently they were the only ones of which reliable maps exist (4). This is not surprising since the glaciers on the eastern and southern side of the group are only a few hours walk from the main caravan route from Kashmir to the upper Indus valley, Gilgit, Hunza, the Pamirs and East Turkestan. Here the first detailed observations were

THE NANGA PARBAT MASSIF

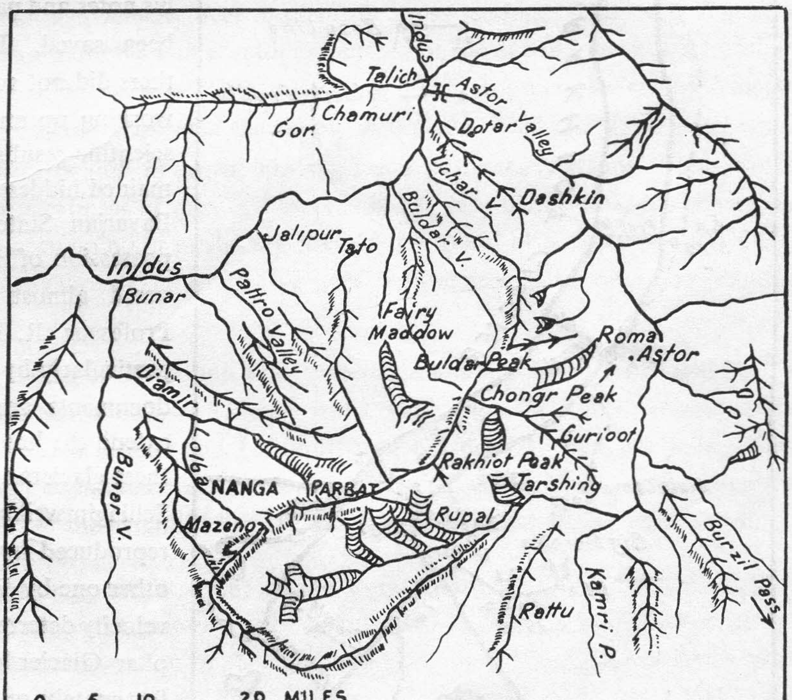


Fig. 1

made already 100 years ago. The brothers Hermann and Adolf Schliagintweit of Munich had already made as young students fundamental observations of glaciers of the Alps (15). Consequently the East India Company, at the recommendation of the famous German scientist Alexander von Humboldt, charged the three brothers Hermann, Adolf and Robert Schlagintweit with a geomagnetic survey of India (9). The brothers travelled three years in India ; they extended the field of their research considerably. Adolf Schlagintweit in particular made extensive observations on the glaciers along the northern border of the sub-continent. He visited during these studies in September 1856 some of the glaciers on the eastern and southern side of Nanga Parbat, took very extensive notes, and made sketches and several paintings of the glaciers (11). Unfortunately Adolf Schlagintweit who had crossed the Kuenlun, was murdered at the age of only 28 years in August 1857 at Kashgar. Most of his notes and paintings have, however, been saved. But his surviving brothers did not succeed in finishing the working up and publication of the scientific results (16) ; most of it remained hidden in the archives of the Bavarian State Library and in the possession of relatives until rediscovered almost a century later by Professor R. Finsterwalder (4) and particularly by W. Kick (9). These documents are most valuable as they extend the knowledge of the state of these glaciers a century back. One of Schlagintweit's paintings has been reproduced by Finsterwalder (4), another one by W. Kick (11). Even a velocity determination of the Chhungphar Glacier by Schlagintweit exists, fortunately quite near the location of later determinations which allows a comparison of the measurements.

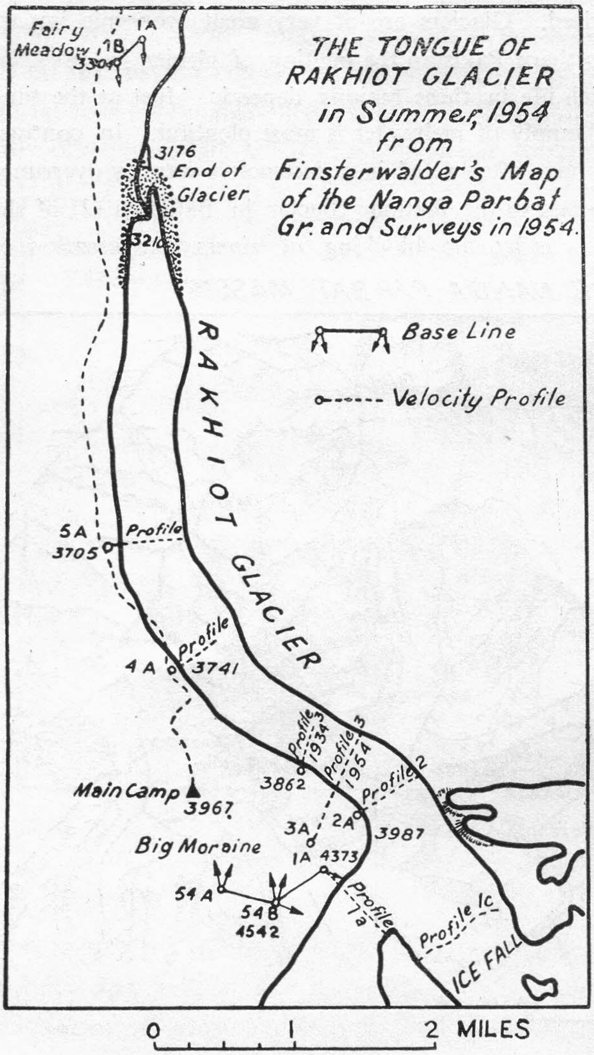


Fig. 2

After Schlagintweit no systematic work on the glaciers of Nanga Parbat was done until the German expedition of 1934. During this expedition R. Finsterwalder produced by terrestrial stereophotogrammetry a map of the whole Nanga Parbat group at a scale of 1 : 50,000 (4). Until recently this was the only large scale map of high accuracy of any substantial region of the Himalayas and Karakoram. It establishes the state of many of the glaciers in 1934 for comparison with later determinations. The basic photographs permit in many regions, particularly near the glacier snouts, even a much more detailed representation than that of the map. In addition Finsterwalder measured by stereophotogrammetry the velocity of the ice motion in four profiles on the Rakhiot glacier of the northern side and one profile on the Chhungphar and Bazhin glaciers in the Rupal valley of the southern side (4). A comparison of Finsterwalder's results with Schlagintweit's painting shows that in 1856 the Chhungphar and Bazhin glaciers extended further and that the former was thicker than in 1934. This corresponds to the decline of the glaciers since the middle of last century which has been noted in many parts of the world (4).

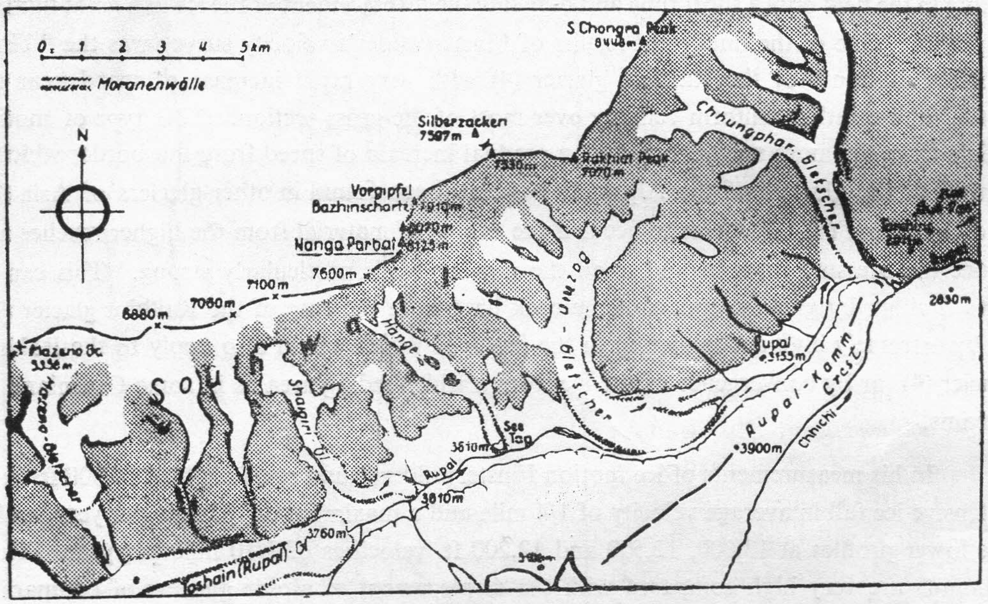
The stereophotogrammetrical determination of ice movements has the advantage of taking in the field only a short time and of giving the displacement of the ice at a great number of points. One of the important results of Finsterwalder's velocity survey was the " block schollen motion " of the Rakhiot glacier (4) with very rapid increase of speed near the border and a rather uniform velocity over most of the cross section. This type of motion differs from the more normal one with a gradual increase of speed from the border which is typical of the glaciers of the Alps. It has also been found in other glaciers of Asia (14) and Greenland (1). It seems to occur if the supply of material from the higher reaches and hence the pressure from behind upon the moving ice is particularly strong. This can be caused either by great steepness of the rock base as in the case of the Rakhiot glacier (13) or by extremely high accumulation in the firn area which would also apply to the Rakhiot glacier (4), or by convergence of the ice from a wide feeding area as in some Greenland ice streams.

In his measurements of ice motion Finsterwalder found at a height of 14,000 ft. in an extensive ice fall in average velocity of 1/4 mile and a maximum of 1/2 mile per year, and at the lower profiles at 13,000, 12,500 and 12,200 ft. velocities of 1/10 mile per year. These amounts are very high compared with the displacement of alpine glaciers of comparable size ; but other glaciers of the neighbouring Hunza Karakoram have similar speeds (14).

The measurements on the Rakhiot glacier were repeated by W. Pillewizer (13) 20 years later. He found that the glacier front had retreated by 500 yards. Most glaciers of the world have shown a diminution of their tongues between the thirties and fifties of this century. The volume loss extended, however, only one mile from the front ; higher up the glacier surface had not diminished since 1934. Measurements of the ice motion gave the rather unexpected result that the velocity on all comparable cross sections was bigger than 20 years earlier. The increase seems significant even taking into account possible seasonal and diurnal variations. The glacier showed again the block schollen motion.

The higher speed and identical height of the glacier surface outside the lowest past suggest that in 1954 the accumulation in the higher part of the glacier was bigger than 1934. It would be very interesting to learn whether the greater supply of ice from above has now halted the retreat of the tongue and has possibly converted it into an advance.

In September, 1958 W. Kick from Regensburg in Germany accompanied by the author and his wife visited the eastern and southern sides of the Nanga Parbat group. Kick made a stereophotogrammetrical survey of the lower parts of the glaciers of the Rupal valley, Chhungphar, Bazhin, Shaigiri and Toshain, and of the Sachen glacier west of the district capital Astor. He measured the velocity of the ice on the Chhungphar (at 10,000, 10,500, 12,500 ft.), Bazhin (12,000 ft.) and Sachen (12,500 ft.) glaciers. The measurements have not yet been fully evaluated, but some popular descriptions of the work are available (10, 11). Most of the observations have been taken near points used by Finsterwalder 24 years earlier,



THE GLACIERS OF THE SOUTH SIDE OF NANGA PARBAT.
From R. Finsterwalder's Map simplified by W. Kick

Fig. 3

and a comparison will be possible. The lower parts of the glaciers have become generally less thick than in 1934, and the snouts have retreated. A painting of the Sachen glacier by Schlagintweit which Kick has found (11), shows that the right lateral moraine has since then considerably grown. This indicates a greater thickness of the glacier at some time between 1856 and now. Today the surface of the glacier lies again considerably below the crest of the moraine thus indicating a shrinking of the glacier since its highest level.

The surface of the Chhungphar glacier which already in 1934 was lower than in 1856 has decreased in its lower part from 1934 to 1958 by about 80 ft. as shown by two photographs taken from the same point (11). Like Pillewizer on the Rakhiot glacier Kick found that, notwithstanding the recession of the glacier end, the velocity of the lower part of the Chhung-har glacier was now bigger than in 1934. At the time of Schlaginweit, 100 ye-rs ago, the speed had also been bigger than in 1934. It is in this case too unlikely that the speed differences are wi hin the range of the normal short period variations. The Bazhin glacier has somewh t shrunk since 1934.

Simultaneously with the glacier survey some observation of the heat economy and ablation on the Chhungphar and Bazhin glaciers were made. The results wil be published elsewhere. The mean daily ablation of the glacier ice at a height of approximately 11,000 ft. in the middle of September was about 3". Considering the rather advanced season this is a very high value. It suggests for the whole summer season an ablation of 30 to 40 ft. of ice ; this is in good agreement with previous tentative calculations of Finsterwalder (4).

During the last years a number of other glaciers in Pakistan have been surveyed with respect to size and speed (7, 8, 14). But these surveys have generally been done in connection with mountaineering expeditions, and the time for a repetition to establish the trends is quite uncertain. In view of the value of glaciers as integrating indicators of climatic variations and of their econoimcal importance a systematic survey should be initiated. For the individual glacier an interval of six years would be satisfactory. A representative sample of the glaciers of Pakistan can probably be covered by a specially train d surveyor and an assistant in three summers. The winter can be used for the evaluation of the results. A very small outlay, financially and in manpower, would give results of great economic and scientific interest.

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A COTTON-WHEAT FARM IN HYDERABAD DISTRICT, WEST PAKISTAN

LUTHER H. GULICK, Jr.

Fulbright Research Scholar in Pakistan, 1959-60.

IN the part of Hyderabad District which is perennially irrigated by canals from the Sukkur or Lloyd Barrage, cotton in the summer or *kharif* season, and wheat in the winter or *rabi* season are the dominant crops (Fig. 1). Other crops are raised, of course, such as bajra (millet) and jowar (sorghum) in the *kharif* season, berseem and oilseeds in *rabi*, and vegetables and orchard crops at varying seasons and throughout the year. Near Hyderabad City some entire farms specialize in vegetables and fodder production, but the overwhelming majority of farms in the Sukkur Barrage area of Hyderabad District devote more land to and derive the largest part of their income from the cotton and wheat crops.

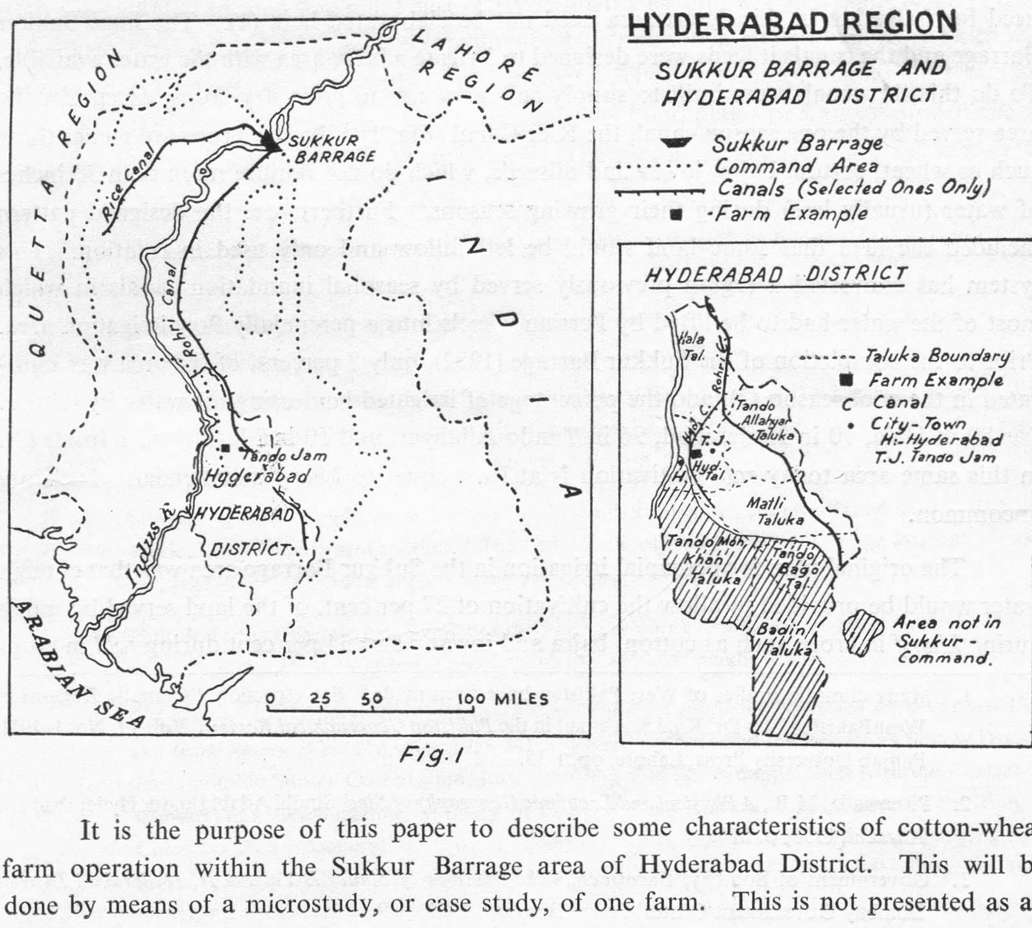

Fig. 1

It is the purpose of this paper to describe some characteristics of cotton-wheat farm operation within the Sukkur Barrage area of Hyderabad District. This will be done by means of a microstudy, or case study, of one farm. This is not presented as an average or typical farm if, indeed, such could be determined. A farm is average in some ways and not in others. Indications of how typical the chosen example is, will be included, however. Studies dealing with the basic units by which man organizes and manages the land and all its utilized resources are fundamental to geography. In an agricultural area this means studies of farm units in terms of such phenomena as their size, land use, crops and crop combination, physical character of land and other resources, use of water, techniques of cultivation, marketing of products as against home consumption, ownership and labour conditions and relations, income, and current problems. Also of great importance are the changes and trends visible in these patterns, and the past development of existing patterns without which the present can hardly be understood. The study which follows is not complete in terms of the preceding list ; on the other hand it will illustrate the idea. It will also add to the information available on a part of Hyderabad District and the Lower Indus Valley region in general.

Before proceeding to the specific example, a description of the irrigation pattern within the perennial areas served by the Sukkur Barrage is extremely enlightening. The need for irrigation in this desert area need not be elaborated here (1). The huge Sukkur Barrage and the canals it feeds were designed to irrigate a large area with the water available. To do this the canals were built to supply enough water to grow dry crops, except for the area served by the one season canal, the Rice Canal (Fig. 1). By dry crops are meant those such as wheat, cotton, bajra, jowar and oilseeds, which do not require more than 36 inches of water (usually less) during their growing seasons. Furthermore, the designed pattern included the idea that some land would be left fallow and only used in rotation. This system has converted a region previously served by seasonal inundation canals in which most of the water had to be lifted by Persian wheels into a perennially flow irrigation area. Prior to the completion of the Sukkur Barrage (1932), only 7 percent. of the area was cultivated in the cool season (2), and the percentage of irrigated land using lift water by talukas was 80 in Hala, 70 in Hyderabad, 96 in Tando Allahyar, and 50 in Matli (Fig. 1 Inset) (3). In this same area today *rabi* cultivation is at least equal to *kharif* and Persian wheels are uncommon.

The original plan for perennial irrigation in the Sukkur Barrage area was that enough water would be provided to allow the cultivation of 27 per cent. of the land served by canals during *kharif* in crops such as cotton, bajra and jowar ; and 54 per cent during *rabi* in crops

1. Many climatic studies of West Pakistan have been made. See especially "Climatic Regions of West Pakistan" by Dr. Kazi S. Ahmad in the *Pakistan Geographical Review*, Vol. VI, No. 1, 1951, Panjab University Press, Lahore, pp. 1-35.

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3. Government of Bombay, *Gazetteer of the Province of Sind. B Volume II, Hyderabad District*, Bombay Government Central Press, Bombay, 1927, p. 9.

like wheat and oilseeds. Canals were therefore designed to carry one cusec of water for each 370 acres they served (1). Seventy-three percent of the land served was to remain fallow in *kharif* and 46 percent in *rabi* Nineteen percent. would be fallow all year. In actual practice, this plan has not worked out. During *kharif* 30 to 35 percent is irrigated, more than the planned 27 per cent ; and in *rabi* 30 to 35 per cent is also irrigated, much less than the 54 percent planned (2). This means that about two-thirds of the land served by canals is fallow in each season. No wonder the area looks anything but completely irrigated and used! The failure to achieve the 54 percent planned for *rabi* is largely a result of the fact that the optimum planting season for wheat is a six to seven week period in November and December. The canals cannot provide sufficient water for wheat planting on more than 30 percent. of the land during this period (3). Early and late planting of wheat is not successful and, crops with other planting periods do not occupy very large acreages (4).

The farm chosen to be described in the pages which follow illustrates the general characteristics of irrigation discussed above as well as many others. The farm contains 400 acres of land located five miles east of Hyderabad City on the Tando Jam Road (Figs. 1 and 2) (5). Four hundred acre farms are not at all uncommon in Hyderabad district although average farm size would be considerably smaller. The land straddles the road and the railroad. This is an alluvial area, a part of the Indus flood plains or Central Sind Plain (6). The soil is fine textured and the terrain level. The major irregularities are the man-made

1. Agricultural Department in Sind, "Use of Irrigation Water", *Cultivator's Leaflet No.* 3, July, 1936.

2. Data supplied by S. A. Rashid, Executive Engineer, Nasir Division, Rohri Canal Circle with offices in Hyderabad.

3. Agricultural Department in Sind, "The Irrigation of Dry Crops in the Barrage (Sukkur) Areas Including a Suggested Time-table of Agricultural Operations and Distribution of Irrigation Water", *Agricultural Leaflet No.* 35, March, 1934, pp. 1-6.

4. Interviews with agricultural specialists in Hyderabad District ; Pithawalla, *op. cit.*, p. 233 ; and Agricultural Department in Sind, "The Cultivation of Rabi Oil Seeds in the Barrage (Sukkur) Areas of Sind", *Agricultural Leaflet No.* 30, August, 1932, p. 2.

5. Land Reforms Commission, *Report of the Land Reforms Commission for West Pakistan*, Government Printing, West Pakistan, Lahore, January, 1959, Appendix I.

6. I. S. Fraser, *Report on a Reconnaissance Survey of the Landforms, Soils and Present Land Use of the Indus Plains, West Pakistan* (1953-54), a survey conducted by the Resources Survey Division, Photographic Survey Corporation, Ltd., Toronto, Canada in cooperation with the Central Soil Conservation Organization, Ministry of Food and Agriculture, Government of Pakistan. A Colombo Plan Cooperative Project, February, 1958, pp. 341-355 and accompanying map : *Present Land Use, West Pakistan*, Sheet No. 5, published for the Government of Pakistan by the Government of Canada, Scale 1 : 253, 440.

spoils banks of the abandoned inundation canals which rise ten to fifteen feet above the surface and, with their channels, occupy strips of land seventy to eighty feet wide (Fig. 2) (1)

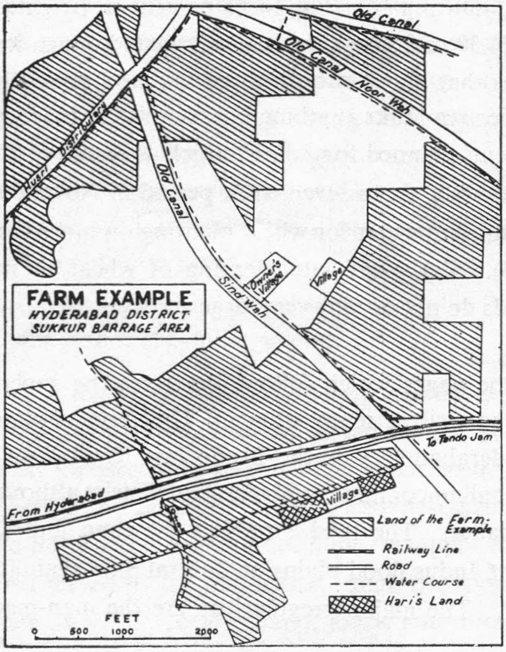

Fig. 2

Farm boundaries are highly irregular and the land, although it is almost in a continuous many-armed piece, is interrupted by road, railroad, old canals and the present canal. This is the result of inheritance combined with the construction of canals, roads, and the railroad. The village where the owner lives is centrally located with respect to the land, but it is not immediately adjacent to any part of the farm proper. The adjoining lands belong to relatives who inhabit the same village.

The farm is irrigated by water courses which lead from the Husri Distributary which in turn comes from the Hyderabad Branch of the huge Rohri Canal (Figs. 1 and 2). The three old canals which cut through or next to the farm were used prior to the 1930's. They were inundation canals from which water had to be lifted. The Husri is a perennial canal from which water flows to the fields.

The water from these canals is allotted on the basis of the acreage at the usual rate of one cusec of water per 370 acres. An additional amount is allowed for use in the orchard and vegetable lands. In total, this farm of 400 acres would have a little more than a flow of one cusec, then. Two water courses leave the Husri to serve the farm ; they also carry water to neighbouring areas. The Irrigation Department controls the flow into the water courses, then the landowner and his labourers manage the flow from the water courses. The Husri flows 335 days a year ; 190 in *kharif* and 145 in *rabi*. There is a period in December for canal clearance when there is no flow.

1. Information concerning the farm was gathered through interviews with the land-owner and field study conducted between February and May, 1960. Abdul Waheed Siddiqi and M.A. Majid, instructors at Sind Oriental College, Hyderabad, assisted me and interpreted. Nothing is gained by using the actual name of the landowner in the text. Information was freely provided, as well as the traditional hospitality, and no restrictions were placed on its use. For possible reference by future research workers, Muhammad Hashim, son of Haji Abdul Karim, the actual owner, supplied the answers to my questions. Father and son manage the farm.

The farm water ditches, the water courses, and the Husri itself are all constructed of earth ; the gates or modules which control the flow from the Husri to the water courses are of concrete, however. The small ditches carry the water to each four acre plot and, at times, to small fields of a fraction of an acre. There the water is allowed to spread over the field, held in by low ridges of earth, or bunds, half a foot to a foot in height, for most crops. In other words it is a basin flooding system. After one field is watered the opening is shut and water is given to another basin. The water is simply allowed to soak in ; there is no planned flow beyond the field and there is no drainage ditch to remove surface or seepage water. A common practice is to allow water to go across one basin through a break in the bund to a second and perhaps third basin. Ploughing, planting and cultivation are done in terms of these separate basins, although preliminary ploughing may ignore the bunds which are then constructed later, and the crop when matured may hide the fact that the land is so subdivided. Much planting is still done by broadcast scattering of the seed upon the moistened rectangular basins.

Today almost all the land of this farm is cultivated but not all at the same time. The pattern is similar to that discussed earlier, but more land is cultivated than on the average farm. Still 65 percent of the land is fallow in *kharif* and 63 per cent in *rabi*, and 26.5 percent of the land is not used at all during the year. Most of the land left fallow is rotated.

The over-all crop pattern for 1959-60 was as follows :

1. *Kharif*, 132 acres : (Fig. 3).	Cotton	58 Acres
	Fodder crops :	
	Bajra	30 ,,
	Jowar	21 ,,
	Maize	15 ,,
	Vegetables :	
	Lady's fingers	8 ,,
2. *Rabi*, 139 acres : (Fig. 4).	Wheat	64 ,,
	Vegetables :	
	Carrots	30 ,,
	Tomatoes	10 ,,
	Fodder :	
	Maize	25 ,,
	Berseem	10 ,,
3. Other season, 15 acres : (Planted in February or March).	Maize and sorghum	15 ,,
4. All year, 8 acres :	Orchard (mango)..	4 ,,
	Forest	4 ,,

Summarizing, 294 acres were used during 1959-60, leaving 106 acres, or 26.5 percent of the land fallow all year. Thirty-three percent was cropped during *kharif* ; 35 percent in *rabi* ; 4 percent in another season ; and 1 percent in orchard and 1 percent in forest throughout the year.

The land devoted to any one crop is not usually located in one block (Figs. 3 and 4). The fact that the land is divided into small basins for irrigation means that there is little advantage in having a crop in one contiguous area. Furthermore, the land is divided for separate cultivation by different cultivators. Some of the vegetables and fodder are concentrated near the road, perhaps to facilitate shipment to town markets. The vegetables grown in the northern part of the farm are adjacent to the canal inspection road along the Husri.

Fig. 3

Fig. 4

Farm operations are not very different for the different crops although there are many variations even from field to field of the same crop. For example, cotton land may be ploughed two, three or four times before it is ridged (bunded) and given its first soaking dose of water, six to eight inches. Then it will be ploughed several more times. On this farm most of the planting is done with the traditional type of seed drill, or *nari*. When this is used the land is levelled after planting. Levelling is done with flat planks of wood on which a man or men stand as bullocks drag them. This may also be done to break clods of dirt. Large wooden hammer-like clod-breakers are also used. After planting the land is given six to eight waterings of two or three inches each. The second watering comes after 40 days of planting ; subsequent waterings continue every two weeks. Cotton planted in rows with the *nari* can be cultivated by ploughing during the early weeks ; other weeding is done by hand with the *rumbi*, a short handled weeding instrument. Cotton is planted in late April and in May, and harvesting starts in September and may continue until December.

The procedure used for wheat, jowar, bajra, and oilseeds is quite similar to this except they receive less water. Wheat is planted in November and harvested in late March and the first half of April. After the soaking dose and a second irrigation after 35 to 40 days, wheat is irrigated only every 20 to 30 days. Vegetables are usually watered more heavily ; the tomatoes, a winter crop, are given weekly water for four months. Tomatoes and some carrots are not planted in the usual basins. Instead seedlings are planted in the sides of ditches which subdivide fields into small rectangles. Lady's finger, a summer crop, is planted in the usual basins.

The harvesting operations are done by manual labour in all cases. Cotton harvest starts in late September and October. In 1959 it was completed within two months. September rains damaged the crop and harvest did not last as long as usual. Women do a good deal of the picking. The fiber is plucked by hand, placed in bags, and then accumulated in larger sacks which can be loaded on trucks, ox-carts, or directly on camel-back for transport to the cotton gins in Tando Jam or Hyderabad. The wheat is harvested in late March and April. The grain is cut by a sickle with a 6 to 8 inch blade. Most of the straw is cut with the grain. In Hyderabad District the most common practice is to tie the cut grain and straw into large bundles and to carry them soon after cutting to the large circular pile which surrounds the threshing floor (a cleared earthen area). Oxen trample and also pull thorny branches over the grain, the straw is piled to one side, and then the grain is winnowed out in the wind and bagged. The first winnowing is done with a long handled, six-toothed, wooden pitchfork. For final grain separation a woven read winnowing scoop about a foot and a half wide and two feet long is used. Each cultivator has a separate pile or piles on the threshing floor ; both the chaff and the grain piles are divided with the landowner. The owner's wheat is transported by ox-cart and truck to Tando Jam or Hyderabad. Chaff is saved for fodder use (mixed with oilseed cake). It may also be used for mixing with mud plaster for building purposes or be bagged and sold in the towns. The vegetables are dug or picked as they ripen and the fodder cut when ready. Some of the vegetables and fodder are sold in the field before harvest. The purchaser then hires local labour to do the harvesting. Sales of these crops are almost always to Hyderabad.

The people involved with the work on this farm are the landowner and his family, the *haris* or sharecroppers and their families, and wage labourers and their families. There are fifteen people in the landowning family. Most of them live in the village designated as " owners " on the map, but several of them are now spending some time at the site of the new " otak ", a subsidiary farm headquarters. (Fig. 2). None of them live in town or city as is often the case with landowners of this region. The landowner and his only son supervise the work of the farm.

The farm labour is provided by sixteen landless *haris*, the traditional farm workers of the Sindhi feudal system, and by an equal number of wage labourers. The families of the *haris* number close to one hundred as do those of the labourers. Traditionally *zamindars* (landowners) have depended upon *haris* to cultivate the land, and wage labourers are still not common. The 1951 census showed that agricultural wage labourers represented only 2.7 percent. of those engaged in agriculture in Sind, and 3.2 percent. in Hyderabad District. Those renting all land tilled were 72.6 percent. in Sind, and 80.7 percent. in Hyderabad District ; almost all of these " renters " are *haris* or sharecroppers and not cash renters (1).

The land which is to be cultivated in any season is divided up into 4 or 5 acre pieces, one for each *hari* or *hari* family. Ten, 11, or 12 acres, then, may be cultivated by a *hari* in a year (two seasons), or more if the family has several sons able to work. *Haris* in turn often hire additional labour during harvest periods ; entire families also work at that time. The *haris* of this farm own ten bullock teams ; the sixteen *haris* share in the use of these teams. The amount of land they cultivate is adjusted to the acreage they can plough and plant with their own tools and bullocks. The average amount of land allotted to each *hari* is often more than on this farm; 6 to 8 acres in *kharif* and 7 to 9 in *rabi* is common. Many landowners own very few bullocks, but in this case the owner has ten teams also ; they are used by the 16 agricultural labourers. Several of these bullocks have won prizes at Village-AID fairs.

The *haris* proceed about the work on their plots fairly independently and in traditional ways. The ploughs, levellers (planks for dragging), the clod breakers, the hand weeders (*rumbi*), the sickles, the typical Sindhi axe, and the carts belong to them. The seed is also paid for by the *hari*. After harvest the crop is divided 50-50 with *haris* if they use their own bullocks. If a *hari* has no bullock team and uses the owner's, the arrangement on this farm is one-fourth for the *hari*, one-half for the owner, and one-fourth for the bullock team. Other examples are known of in which this division is one-third for the *hari*, owner, and bullock team alike. There is some variation in the share arrangement, therefore, but most commonly in Hyderabad District the *haris* have bullock teams and receive a half share of the crop.

In addition to owning or sharing the ownership of a bullock team and of the common farm implements, *haris* also own other livestock and a hut. Most of them have a buffalo for milking and a few goats, sheep, and chickens. Two on this farm have their own horses. Living quarters are one room mud huts with thatched roofs and perhaps a verandah. A thorn wall usually surrounds each family's group of huts, and part of the enclosure is used for a stable with open-sided shelters. The interior of the huts are kept surprisingly clean and neat. Furnishings are few—a *charpoy* (cot) or two, metals storage chest for bedding and clothes, iron pans and pottery jugs (old tin cans now supplement the latter). The mud

1. Government of Pakistan, *Census of Pakistan*, 1951, *Vol.* 6, *Sind and Khairpur State*, *Karachi*, Date of Publication not given, p. 118, and Part II, Table 14, p. 14—2.

walls of the huts have narrow built-in shelves. The cooking and much of the sleeping are done outside the hut. Grain is stored in mud-protected piles within the enclosure; chaff may also be stored in this manner.

Traditionally a share of the crop has been given to persons other than *haris* also. To a certain extent this is still practised by this landowner. The barber who works for the family always gets two bags of wheat and two of millet (bajra)—each bag of two and a half maunds, or about 205 pounds. The blacksmith and carpenter are sometimes paid in grain, but they may be paid in cash. *Haris* often pay these people in grain also. The practice still found in some very traditional villages of paying a revered holy man, or Pir, a part of the harvest before it is divided between *zamindar* and *hari*, is not done on this farm (1).

The wage labourers all come from nearby villages ; the landowner employs only people he knows. They live much as the *haris* do but they do not have their own bullocks. They are paid at a rate of 40 to 50 Rupees per month, plus meals. These labourers work with the owner's bullocks, carts, ploughs and other tools and equipment under the supervision of the landowner. This is a departure from the widespread use of *haris*. It reflects this landowner's desire to exercise direct control over the use of his land. There is a trend in the direction of more *zamindars* wanting to try new techniques on their land. Formerly the *haris* of Sind were occupants-at-will who could be removed without reason, although this did not happen frequently. Now the *hari* is protected (2). This may mean that a landowner who wants to try new practices or crops will have difficulty in changing the traditional methods of the *haris*. This landowner has for some time, however, managed about half of his own land directly using wage labour instead of *hari* labour.

The crops produced on this farm are disposed of in various ways. The landowner is largely a commercial operator; the *haris* operate partly on a subsistence basis. The entire cotton crops is sold by the owner. The *haris* are then given their share in cash. Some *zamindars* divide the cotton itself and leave it up to the *haris* to market their own share. The wheat is divided after the threshing. Most of the *haris*' share from four or five acres, 20 to 25 maunds, is consumed by them and used for seed. They may sell a bag of two and a half maunds or so, but seldom any more. On the other hand the owner sells the bulk of his share. Fodder crops are sold in Hyderabad or sold on contract in the fields. *Haris* use part of their shares for their bullocks, buffalo, and the other livestock they may have. The vegetables are taken to market daily during their harvest period. They may go by cart, tonga, horse, and even bicycle to the Hyderabad market commission agents. At the end of a month the account is cleared with the agent and the money is divided. Occasionally

1. Interview with Abdul Waheed Siddiqi about the village Pat, Dadu District, January 28, 1960.

2. Sir Malcolm Darling, *Labour Conditions in Agriculture in Pakistan* 1953-54, for Government of Pakistan, Ministry of Labour, Karachi, Manager of Publications, Karachi, 1955, pp. 32 and 46-47.

purchasers for the Karachi market come to the farm and buy vegetables. The fruit from the orchard is consumed locally. The farm has many commercial connections, therefore, but it also provides the staple food in a subsistence manner for those working on it.

Three of the *haris* of this farm also own small farms of their own of 4, 5 and 7 acres. These farms have been inherited ; *haris* generally have no way of accumulating the minimum of one thousand rupees needed to buy even an acre of already cultivated land. One such *hari* lives in the village just south of the main farm example ; his land is on both sides of that village (Fig. 2). His seven acres are planted to a combination of crops similar to that of the large farm. In *rabi* 1959-60 he had 3 acres of wheat and a little less than 1 acre of carrots ; the balance of that acre was in berseem. During the previous *kharif* season he grew 2 acres of cotton and a little bajra. Cotton and wheat are the major crops on farms of all sizes in this, the perennially irrigated Sukkur Barrage, area of Hyderabad District. Only near the city of Hyderabad and on a few scattered other farms are there crops which overshadow these two.

These are some of the salient features of a cotton-wheat farm in the Sukkur Barrage area of Hyderabad District. The amount of land cultivated during the various seasons is very similar, though a little above, the general percentage found in this perennially irrigated area. The large proportion of cultivation done by wage labourers on this farm is unusual. The farm is more conveniently located with respect to transportation facilities than many. The relatively large vegetable and fodder crops find a market in Hyderabad City, only five miles distant, and beyond. Fruit is often produced for sale on other farms and, even on farms not on main roads, a special fruit may be sent to market, such as mangoes, bananas, mulberries, guava, or the berries called *ber*. In this area bananas are becoming increasingly popular since they have been the most profitable crop grown. A small acreage of bananas will soon be planted on the farm discussed, as a matter of fact. In most respects this farm is not at all unusual.

The pattern of agriculture found in this part of Hyderabad District, with wheat and cotton as major crops, has evolved since the flow of perennial water started from the Sukkur Barrage less than thirty years ago. Relatively speaking this is an area of stability and successfully operating farms today. Waterlogging and salinity are not yet threatening to reduce productivity as they are in other Sukkur Barrage areas, notably along the Rice Canal on the right bank and in Khairpur District on the left bank. Neither are the vast changes and problems such as those of the neighbouring Lower Sind Barrage areas to be found.

VARIABILITY OF RAINFALL AND ITS BEARING ON AGRICULTURE IN THE ARID AND SEMI-ARID ZONES OF WEST PAKISTAN*

KAZI S. AHMAD AND MUBASHIR L. KHAN

University of the Panjab, Lahore

THE arid and semi-arid zones of West Pakistan are undergoing rapid transformation. Vast tracts of land hitherto lying barren for want of water are being increasingly put to plough. This has been made possible by the irrigation schemes which are being executed in various regions of the country. By the end of II Five Year Plan in 1965, some 1.5 million acres would be added to the present cultivated area of 31 million acres.(1) In addition there are 29.5 million acres which could be brought under cultivation.

It is a well known fact, that in the arid and semi-arid areas the relation between man and environment is an extremely critical one. These lands cannot be used beyond their capability and whenever efforts have been made to the contrary, they have always resulted in huge financial losses and economic setbacks. It is, therefore, important to realize that the best way of procuring permanent benefits for irrigation agriculture in such regions is to devise a pattern of land utilization which should be in complete consonance with the environmental conditions. This can be accomplished only through a proper understanding of the land-water relationships and scientific adjustments of land utilization accordingly.

It may be pertinent to emphasize that rainfall being the primary, inexpensive and most widespread source of water, on the earth, should deserve closest attention. This is especially important for the arid and semi-arid areas where the rainfall is scanty and of greatest value. It is, therefore, necessary that all factors determining the effectiveness of rainfall should be thoroughly studied in order to assess its practical utility.

Variability is one of the most important factors affecting the efficiency of rainfall. This is especially so from the point of view of agricultural pursuits. Wallen (2) has therefore rightly suggested the use of variability parameter in the climatic indices in order to show the comparative utility of land areas for agricultural purposes. In the arid and semi-arid zones especially where the limits of variability fluctuate so widely, the amount of rainfall is reduced to an extremely poor index of the effectiveness of rainfall and the use of variability parameter becomes of still greater importance. It is therefore desirable to support the proposal of Wallen (op. cit. p. 155) for the introduction of this factor along with that of evapo-transpiration in all types of climatic classifications.

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The isohyetal map of West Pakistan Fig. 1 shows at once the scantiness of the amount of rainfall received in the country. The moisture types have also been shown on the same map after Thornthwaite's method. It may be easily seen that the arid and semi-arid zones cover bulk of the total area of the country, nearly 88%. The rainfall received in these areas is less than 20″ per annum which is marginal to cultivation. Incidently this is also the region of maximum concentration of agricultural activity in the country. Even a small increase or decrease of rainfall may spell success or failure of the crop. This is exactly what makes the study of variablity so important in context of agriculture.

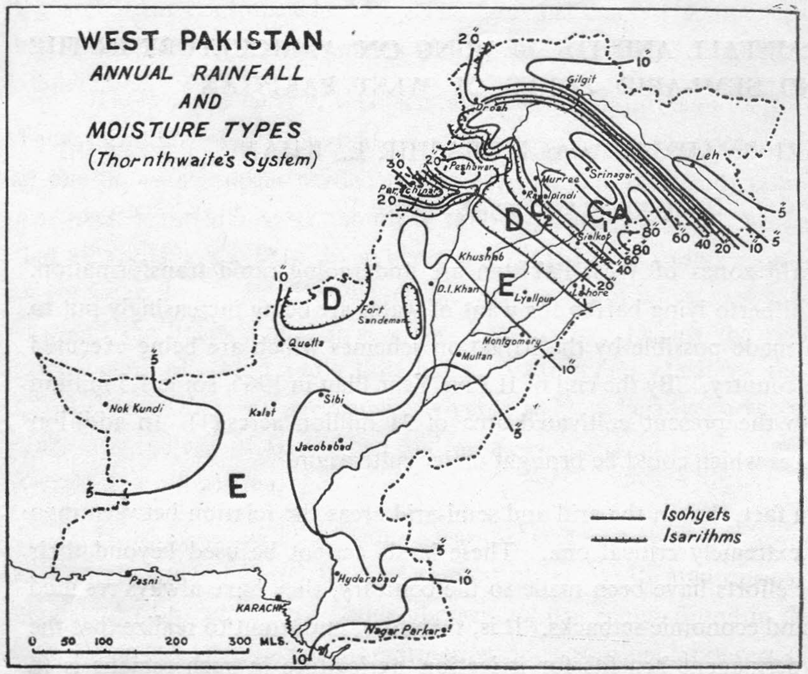

Fig. 1

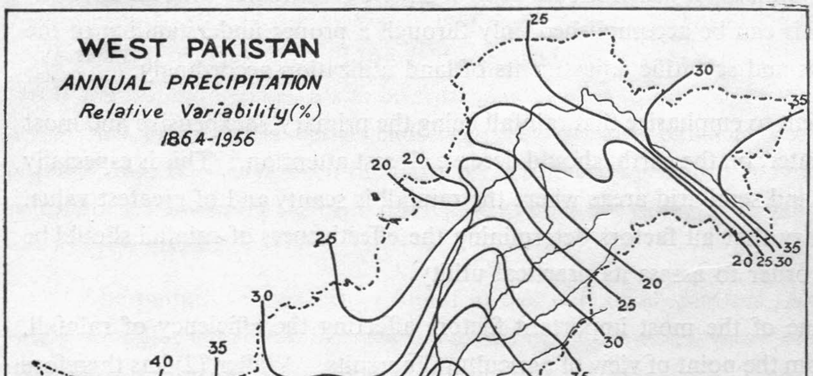

Fig. 2

Variability of rainfall

Various methods have been employed to study the variability of annual rainfall. The isolines of variability have also been drawn for the non-arid regions in order to study the trends of parameters.

Fig. 2. shows the distribution of relative variability (R. V.) which expresses mean

deviation as a percentage of the arithmetic mean ($\bar{x}$) for the period of 1864-1955. It may be seen that the region of maximum variability (60%) stretches along the Arabian Sea Coast from the delta of R. Porali eastward to the mouth of the Great Rann of Cutch. In the southern Indus plain the variability ranges from 47 to over 60%, in the northern Indus plain from 25 to 50% and Baluchistan from 25 to 55%. In the non-arid areas in the Himalayas and Koh-i-Sufed, it is less than 20%. On the leeward side, in the regions of Hindukush and Karakorams it increases from 21% in S. Chitral to 35% in Ladakh.

It has been noted by Conrad (3) that the values of R. V. are not independent of ($\bar{x}$) so that the former values are not directly comparable with one another. A hyperbolic relation has been demonstrated to exist between R. V. and it is beyond the turning point of the curve, near 28 inches of rainfall that R. V. becomes immune to the amount of rainfall. In order to make the values of R. V. independent of $\bar{x}$ isanomals of R. V. have been drawn from the standard curve prepared by Conrad showing the interrelation between R. V. and ($\bar{x}$) for the world as a whole. These isanomals have been drawn in Fig. 3. It may be seen that the highest positive anomalies are found near the Indus delta along the Arabian seacoast, which is the region of maximum variability in the country. In contrast the rainfall in the Chagai-Kharan desert although small in amount is far less variable than the normal. The same is true in the Trans-Himalayan arid zones. Another significant feature of the map is the normal variability (±5%) in the Himalayan tracts, the Agencies of Kurram and Waziristan and the N. E. Lobe of Baluchistan.

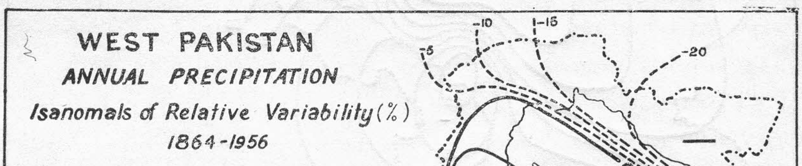

Fig. 3

Fig. 4. shows the distribution of another numerical property of dispersion, the coefficient of variability (C. V.). The coefficient is based on the standard deviation (σ) instead of mean deviation and expresses the former in percentage of ($\bar{x}$). Since all

departures from ($\bar{x}$) are squared in the calculation of standard deviation, greater stress is laid on the extremes than in the mean deviation. One essential feature of this method is that it successfully brings into relief such areas as are characterized by extremes. Looking at Fig. 4. we note that an area with really high variability is brought out clearly by this method which was obscured by the method of relative variability. This is the region around Jacobabad and Sukkur, noted for its extremities. This will be appreciated from a study of Fig. 5, 6. Otherwise, the map is quite identical to the map of relative variability and bears all the essential characteristics of the latter. Increase in the values of variability is what should be expected, ceteris paribus.

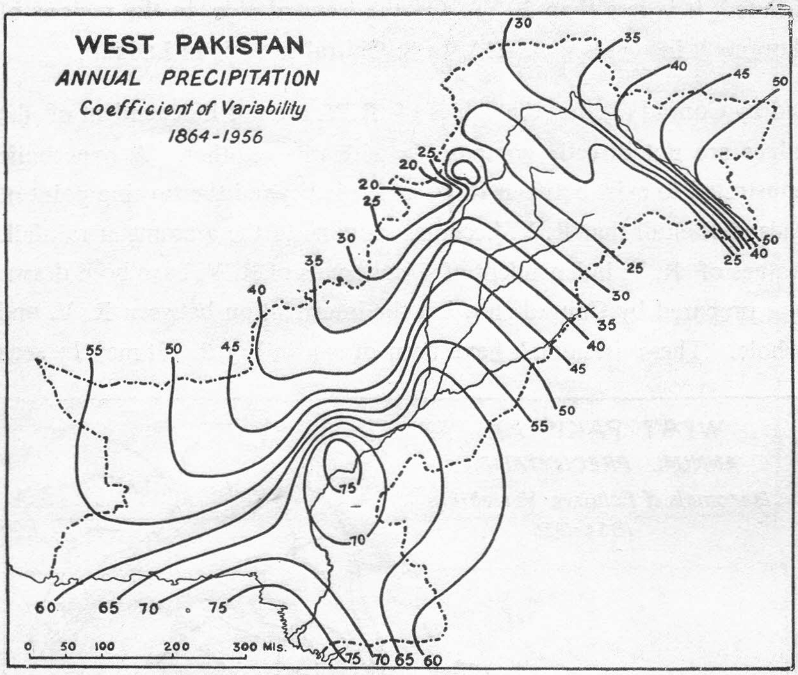

Fig. 4

The absolute amounts of precipitation are shown on Fig. 5 and 6. Fig. 5. shows the highest annual precipitation ever recorded during the observational interval, expressed as percentage of the mean rainfall. Although it is important for the construction of such maps that the length of period should be uniform but this being not the case in this study, a few disjointed values have been left out of account. The highest rainfall so far recorded in the country was 416% of the average at Jacobabad. The lowest annual precipitation recorded in a single year is shown in Fig. 6. expressed as percentage of ($\bar{x}$). A completely rainless year was observed at Nokkundi, in the Chagai-Kharan desert. Rainfall amounts, as low as 30% of the average have been recorded almost everywhere in the Indus plain and the quadrangle of Baluchistan plateau. An important characteristic of variability is obtained by comparing the Fig. 5. and 6. i. e., extremes of rainfall have been recorded in the arid zones, a feature common to all deserts of the world.

Gherzi's index of variation (4) has also been tried to study the problem. The method is an improvement on Hellmann's quotient of variation, expresses the ratio between the difference of highest and lowest rainfall recorded at a station and the average amount.

Inefficient as the method is, it does not fully explain the essential features of variability. The indices are drawn on Fig. 7. The only notable feature of the map is the relatively high variability in the Thal desert and low variability in the Tharparkar region in contrast to the conditions, pre vailing in the southern Indus plain.

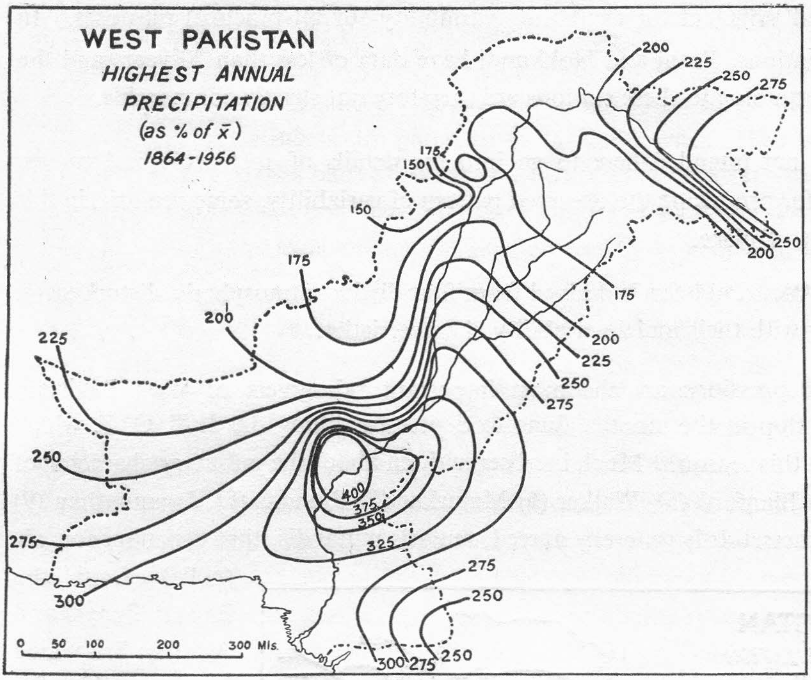

Fig .5

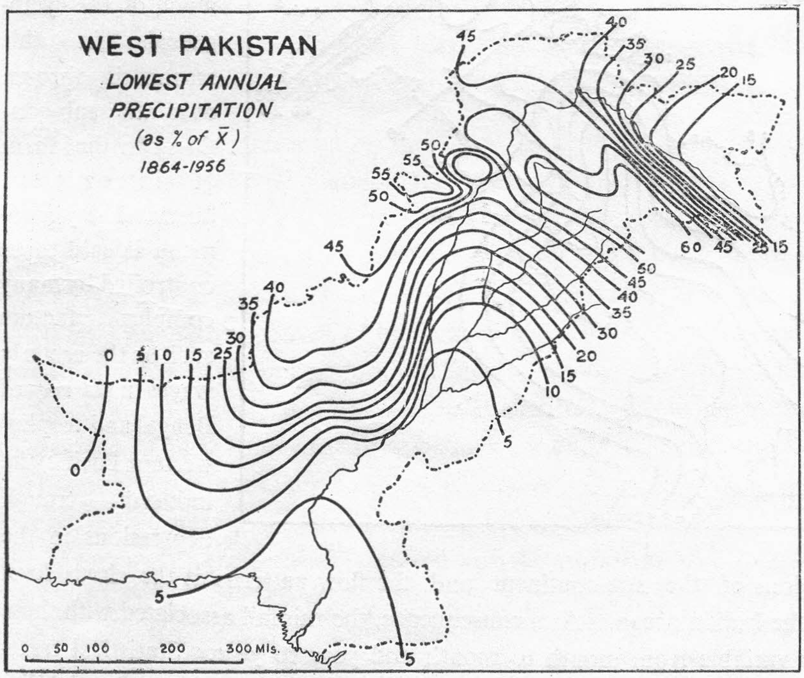

Fig. 6

Before concluding the discussion on variability, it is important to point out that by increasing the length of the interval of observation the variability also increases. The concept is commonly repeated in the literature on climatology. The relative variability has been calculated for two stations situated in the arid zone, Karachi and D. I. Khan, for different lengths of observational interval. These values are graphed in Fig. 8. From the nature of the curves, it may be appreciated that the rise in variability with the increase of interval is not infinite as usually supposed. In fact, the curves of R. V. are asymptotic, become invariant to the increase in period beyond 30 years, an interval which should therefore be considered sufficient for evaluating variability for all practical purposes. In our study, only two stations, Pasni and Nokkundi have data of less than 30 years and the values of variability pertaining to these stations are therefore not strictly comparable.

Although, it is not intended here to go into the details of meteorological causes, which are responsible for producing the observed pattern of variability, some remarks in this respect will not be out of place.

The rainfall of West Pakistan is derived from four distinct atmospheric disturbances. These are given below with their main variability characteristics.

1. Monsoon depressions are the most important rain-givers of West Pakistan. These depressions develop in the months, June to September along the I. T. C. Z. which lies over South Asia in this season. Much has been written about the pulsatary character of monsoonal activity by Blanford (5), Walker (6) Malurkar (7) Ramdas (8), Jagannathan (9) Naqvi (10, 11) and others. It is generally agreed, mutatis mutandis, that the monsoon air (mTu) from the Bay of Bengal and Arabian Sea which is responsible for much of the cyclogenesis in this season is thrown over the sub-continent in the form of intremittent bursts. The phenomena is said to be controlled by many complex factors such as the easterly waves in the Bay of Bengal and tropical western Pacific, the induced trough depressions in the extreme northern regions of the sub-continent and the flow patterns at the cirrus level over south Asia and the Indian ocean. As a consequence, the rainfall associated with these depressions is highly variable from month to month and year to year. Statistical treatments done by Iyer (12), Naryan (13) and Naqvi (14) show that the coefficient of variability of monsoon rainfall is as high as 90% in the central regions of the country. This high

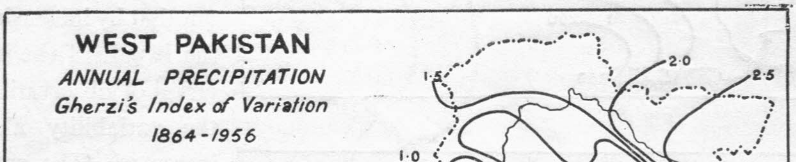

Fig. 7

variability is very well reflected in Fig. 3. of this study where variability is everywhere above normal in the region receiving 50 to 75% of its annual rainfall in the monsoon season. The zero-isoline wonderfully separates the monsoon regime to the east and south and winter spring regime to the west and north of the country.

2. Western disturbances are the second important source of rainfall. These depressions which travel from the Mediterranean sea eastward over the Middle Eastern countries are observed over the country from December to May, although induced trough depressions may continue even in the monsoon season. These disturbances are most frequent during the period, December to March. Consequently most of the rainfall during this period is associated with these depressions. Investigations conducted by Ramanathan (15), Venkiteshwaran (16), Chaudhry (17), Mooley (18), and Chakravortty and Basu (20) about the development and behaviour of these disturbances reveal that these may be easily likened to the extratropical depressions resulting from the juxtaposition of polar and opical airmasses along the Polar Front. It has been frequently observed that prolonged activity of these disturbances tends to retard the development of monsoons and *vice versa*. Another important feature of these disturbances is that in contrast to the monsoonal depressions, they are much more steady and regular. As a result, the variability of winter precipitation is low. This is at once borne out by Fig. 3 where all regions receiving 50 to 100% of their annual rainfall during the winter and spring months have variability below normal. Nokkundi with its scanty annual rainfall of 1.49″ but all of its falling in the winter spring months has a variability about 45% below the normal.

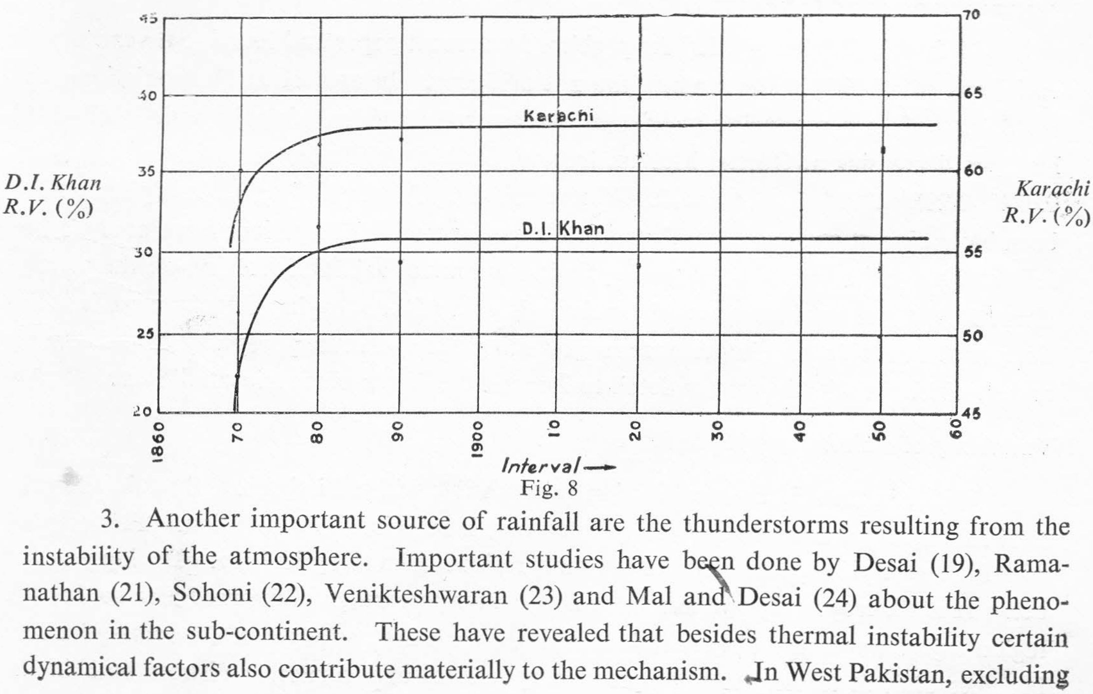

Fig. 8

3. Another important source of rainfall are the thunderstorms resulting from the instability of the atmosphere. Important studies have been done by Desai (19), Ramanathan (21), Sohoni (22), Venikteshwaran (23) and Mal and Desai (24) about the phenomenon in the sub-continent. These have revealed that besides thermal instability certain dynamical factors also contribute materially to the mechanism. In West Pakistan, excluding

the period December—February thunderstorms are present practically throughout the year. In the regions of Punjab and North Western Frontier they show double maxima, one in April and the other in July and August. The April maximum is secondary and mostly associated with the western disturbances. In Sind and Baluchistan, they reach maximum strength in July (25). Since no elaborate statistical study of the variability of thunderstorms has been undertaken so far, it is difficult to say anything to that effect. A study of their variability for a limited period, 1914-23, shows that their R. V. at Karachi is 35.45% and at Lahore, 23.70%. From these figures it appears that the phenomenon is less variable than the monsoonal activity. Low variability of the phenomenon is also reflected in the negative isanomals in the northern parts of the country where bulk of the annual rainfall is received during the spring months.

4. Another source of rainfall in West Pakistan and often overlooked are the tropical revolving storms of the Arabian sea. These 'cyclones', as they are called in our literature, develop in the autumn and spring and after recurving strike the coastal areas of the country. These perturbations are notorious for their vagaries and erratic paths and appear to be chiefly responsible for the highest variability of rainfall around the Indus delta. This is obviously the region representing the most frequented track of these cyclones. After reaching the land-areas they immediately die out after releasing the latent energy and do not penetrate far into the interior. These 'cyclones' develop very rarely on land (See Veryard 26).

Secular and Periodic Variations

Mubashir (27) has studied the problem in a recent paper and found that year to year variations of rainfall in the country are not arbitrary. In case of secular variations, the coefficients of liner, regression reveal that the annual rainfall during the period 1871-1955 has been decreasing at Quetta, Multan, Lahore, Sialkot and Peshawar at the yearly rate of 0.024″, 0.22″, 0.030″, 0.011″ and 0.040″ respectively. At Karachi and Rawalpindi, it has been increasing at a rate of 0.014″ and 0.053″ per annum. The periodogram analysis has indicated the existence of a 3-4 year cycle in the annual rainfall involving on the average about 10% of the total energy of the series. It goes without saying that these cyclic variations are of considerable importance in governing the economic prosperity of the country and should be studied in greater detail to forecast the future economic conditions.

Variability of Rainfall and Agriculture

While in the arid zone cultivation is impossible without irrigation, the rainfall in the semi arid zone, as has already been pointed out, is marginal to cultivation. This coupled with high variability poses some of the most serious risks to agriculture. During years of better rainfall, crops are good and there is a greater percentage of matured area so that the region enjoys a measure of economic stability. With the onslought of drought agriculture becomes difficult leading to widespread crop-failures and economic distress both in the irrigated and non-irrigated areas. This introduces an element of instability in the economy of these areas which has to be provided against by alternative assured sources of water-supply.

It is often remarked that irrigation affords a high degree of protection to agriculture from the ravages of drought. This is true only to a limited extent in our arid and semi-arid areas where storage facilities do not exist and the drought years affect considerable reduction in the canal water supplies. This ultimately throws large areas out of cultivation. The following example which tries to correlate rainfall with the wheat acreage will serve to illustrate the point.

Fig. 9. shows the year to year variation of wheat acreage and September ranifall in the Punjab since 1900. September is the month when seedbeds are prepared by the farmers. Consequently the rainfall in this month has maximum control on the extent of wheat acreage. Although there are some non-arid areas in the Punjab but wheat cultivation in these areas is so negligible that it will not materially affect on the correlation sought below. Table 4. shows the correlation data between the September rainfall (x) and Annual wheat acreage (y) in the Punjab.

The correlation co-efficient (r) of +0.62 with a probable error (F) of only a tenth of that amount is significant. The co-efficient would improve if the October and November rainfall is also taken into consideration. Unakar (28) has shown a correlation coefficient of +0.63 between the wheat acreage and September to November rainfall of the Punjab for the period 1892-1927.

Beside producing great variations in the cultivated area, the variability of rainfall also changes the crop structure from year to year. When the rainfall is good, the farmers are induced to devote greater areas to rice, wheat, oilseeds, etc. During dry years there is a reduction in the acreage of above crops and greater proportion is occupied by the drought enduring crops like millets, etc., at the expense of more valuable food and cash crops (see Table 5). This has a further detrimental effect on the economy of dry years.

From the foregoing discussion, it becomes clear that irrigation does not afford immunity to agriculture as is usually claimed and the latter must depend above all things on the natural supplies of rainfall. It is therefore of immense importance that in regions with high variability of rainfall, the problem of land utilization should be adapted to the whole range of environmental conditions. This would necessitate the introduction of such cultures as are not easily susceptible to the year-to-year fluctuations of rainfall. Few suggestions regarding this pattern are made below :

1. In areas with very high variability of rainfall like the Gudu Barrage zone farming should be regulated to the minimum supplies of water that should be normally available

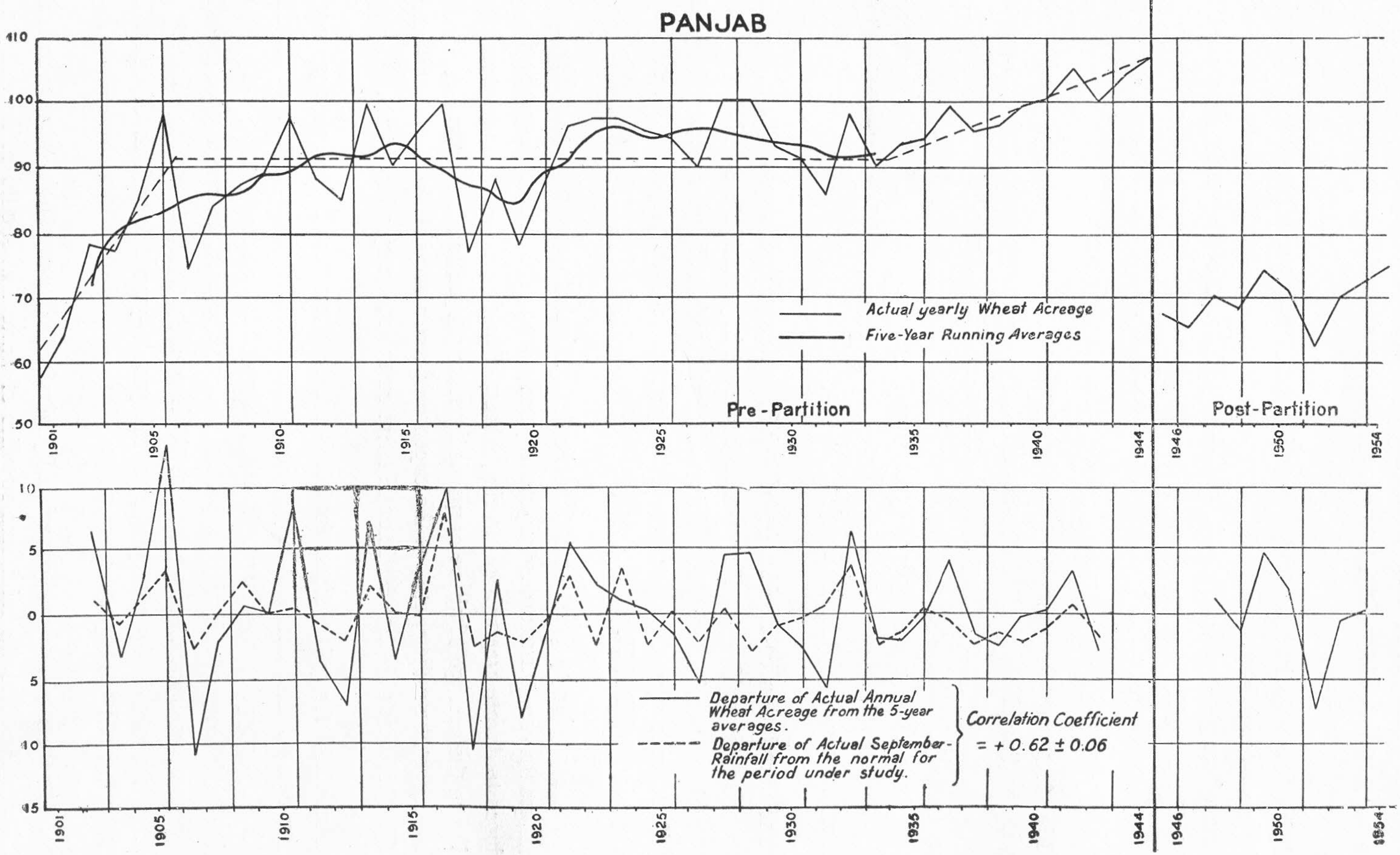
PANJAB
Actual yearly Wheat Acreage
Five-Year Running Averages
Pre-Partition
Post-Partition
Departure of Actual Annual Wheat Acreage from the 5-year averages.
Departure of Actual September-Rainfall from the normal for the period under study.
Correlation Coefficient
= + 0.62 ± 0.06
1901
1905
1910
1915
1920
1925
1930
1935
1940
1944
1946
1950
1954

Fig. 9

from the canals and the duty that it may be expected to perform. Other areas should be developed on the basis of rainfall keeping in view its variability. It may be pointed that even today hundred percent of the cultivation in the Sind and Baluchistan regions is irrigated. Grazing lands should be established with grasses which can stand long periods of drought without being desiccated and Suitable stock should be introduced on these pastures.

2. Animal husbandry should be supplemented by tree-culture. Although afforestation will be accompolished only with difficulty under the present climatic conditions but when well established, trees being more or less indifferent to variability of rainfall will give an element of constancy to the economy of these areas. While selecting the species of trees due perference should be given to food plants adaptable to the local climatic and edaphic conditions and such plants as mulberry castor, etc., that may be grown to supply industrial raw-materials.

3. In areas of moderate variability farming may be continued with the help of irrigation side by side with animal husbandry. Only such crops should be cultivated as can easily thrive under conditions of limited water-supply.

TABLE 1

SHOWING THE ARITHMATIC MEAN ($\bar{x}$) OF ANNUAL RAINFALL AND ITS STANDARD ERROR σ

Station	Data for the period	No. of years	σ (Inches)	$\sigma_{\bar{x}}$ (Inches)
Pasni	1912—1944	24	6.80	0.85
Karachi (Manora Island)	1871—1955	85	7.60	0.64
Nagar Parkar	1871—1920	40	16.08	1.45
Hyderabad	1866—1946	79	7.66	0.59
Nokkundi	1934—1955	23	1.49	0.17
Kalat	1883—1946	55	7.89	0.44
Quetta	1875—1955	75	9.04	0.38
Sibi	1901—1946	33	5.44	0.41
Jacobabad	1861—1956	96	3.85	0.29
F. Sandeman	1901—1946	44	10.26	0.49
D. I. Khan	1863—1955	91	8.72	0.37
Multan	1871—1955	85	6.76	0.46
Montgomery	1871—1955	85	9.99	0.52
Lyallpur	1901—1955	53	13.00	0.72
Khushab	1901—1955	53	14.48	0.82
Lahore	1781—1955	85	19.40	0.69
Sialkot	1871—1955	85	32.10	0.97
Rawalpindi	1871—1955	85	36.06	1.00
Murree	1875—1955	77	59.07	1.49
Peshawar	1871—1955	85	13.22	0.52
Parachinar	1901—1955	48	29.06	0.84
Drosh	1911—1955	41	20.78	0.89
Srinagar	1864—1946	61	32.64	1.02
Gilgit	1892—1958	55	5.07	0.23
Leh	1876—1940	65	3.25	0.19

TABLE 2

SHOWING THE VALUES OF THE COEFFICIENT OF VARIABILITY AND RELATIVE VARIABILITY

Station	(Inches)	(Inches)	C. V. (%)	M. D. (Inches)	R. V. (%)
Pasni	18.97	4.18	61.47	3.13	46.03
Karachi	35.02	5.91	77.76	4.66	61.31
Nagar Parkar	84.04	9.16	56.97	7.51	46.70
Hyderabad	27.33	5.23	68.28	4.44	57.96
Nokkundi	0.65	0.81	54.36	0.64	42.95
Kalat	11.62	3.28	41.57	2.52	31.93
Quetta	10.99	3.31	36.60	2.43	26.88
Sibi	5.61	2.37	43.56	1.87	34.37
Jacobabad	8.48	2.91	75.58	2.11	54.81
F. Sandeman	10.78	3.28	31.97	2.52	24.56
D. I. Khan	12.25	3.49	40.02	2.81	32.22
Multan	14.66	3.83	56.67	3.00	44.38
Montgomery	22.74	4.77	47.74	3.59	35.93
Lyallpur	27.76	5.27	40.53	4.25	32.69
Khushab	35.96	5.99	41.36	5.16	35.54
Lahore	41.66	6.45	33.45	5.26	24.11
Sialkot	30.57	8.97	27.95	7.28	22.67
Rawalpindi	85.36	9.24	25.63	7.42	20.58
Murree	171.14	13.08	22.14	10.44	17.67
Peshawar	23.35	4.83	36.53	3.78	28.59
Parachinar	33.95	5.82	20.02	4.53	15.59
Drosh	32.39	5.69	27.38	4.33	20.84
Srinagar	64.06	8.00	24.51	6.69	20.50
Gilgit	3.03	1.74	34.32	1.39	27.41
Leh	2.44	1.56	48.00	1.09	33.53

TABLE 3

SHOWING THE ABSOLUTE VALUES OF PRECIPITATION AND CHARRIS IDEX OF VARIATION

Station	M (Inches)	Mas % of $\bar{x}$	m (Inches)	Mas % of $\bar{x}$	Gherzi's Index of variation
Pasni	20.49	301.35	0.29	4.26	2.93
Karachi	23.83	313.55	0.47	6.18	3.07
Nagar Parkar	38.53	239.49	0.66	0.41	1.30
Hyderabad	23.30	304.17	0.40	8.61	2.98
Nokkundi	3.32	222.81	Zero	Zero	2.22
Kalat	18.05	228.77	2.85	36.12	1.92
Quetta	17.66	195.35	3.77	41.70	1.53
Sibi	11.92	219.11	1.56	28.67	2.27
Jacobabad	16.02	416.10	0.13	3.38	3.28
F. Sandeman	17.46	170.74	0.79	7.61	1.62
D. I. Khan	20.05	229.93	1.41	16.16	3.28
Multan	20.38	301.47	0.29	4.28	2.97
Montgomery	24.82	248.44	0.99	9.92	1.49
Lyallpur	25.95	199.61	5.38	41.38	1.58
Khushab	29.93	266.69	3.85	26.58	1.80
Lahore	37.80	194.84	6.21	32.01	1.63
Sialkot	54.96	168.41	12.97	40.40	1.28
Rawalpindi	58.84	163.17	18.34	50.83	1.12
Murree	100.30	169.79	37.92	64.19	0.61
Peshawar	27.87	210.82	4.11	31.09	1.79
Parachinar	38.67	133.06	16.52	56.84	0.76
Drosh	40.61	195.42	9.18	44.17	1.51
Srinagar	50.85	155.79	17.62	53.98	1.01
Gilgit	9.66	190.93	2.12	41.81	1.48
Leh	9.10	280.00	0.44	13.53	2.66

TABLE 4

SHOWING THE WHEAT AND RAINFALL DATA FOR THE PUNJAB REGION

Year	Actual	5—year Moving Average	Departure	Rainfall September	Departure from Normal
	10^3 acres			Inches	
1901-2	56.5	..	..	0.94	—1.9
1902-3	64.1	..	..	2.38	—0.4
1903-4	78.2	72.1	+6.1	3.69	+0.9
1904-5	76.8	80.1	—3.3	2.14	—0.7
1905-6	85.0	82.0	+3.0	4.27	+1.5
1906-7	96.5	83.2	+13.3	6.12	—3.3
1907-8	73.9	85.1	—11.2	0.15	—2.6
1908-9	84.0	85.9	—1.9	2.97	+0.1
1909-10	86.8	86.1	+0.7	5.35	+2.6
1910-11	88.8	88.8	0	2.58	—0.2
1911-12	97.3	88.9	+8.4	3.23	+9.4
1912-13	87.7	91.5	—3.8	1.98	—0.8
1913-14	84.7	91.7	—7.0	0.75	—2.0
1914-15	99.2	91.2	+8.0	4.95	+2.1
1915-16	89.9	93.5	—3.6	2.84	0
1916-17	94.7	91.3	+3.4	2.73	—0.1
1917-18	99.3	89.7	+9.6	10.94	+8.1
1918-19	76.8	87.2	—10.4	0.63	—2.2
1919-20	88.1	85.9	+2.2	1.37	—1.4
1920-21	77.5	85.3	—8.7	0.77	—2.0
1921-22	87.9	89.3	—1.4	2.36	—0.4
1922-23	96.2	90.9	+5.3	5.73	+2.9
1923-24	96.7	94.4	+2.3	0.60	—2.2
1924-25	96.6	95.5	+1.1	6.33	+3.5
1925-26	94.8	94.4	+0.4	0.64	—2.2
1926-27	93.8	95.0	—1.2	3.05	+0.3
1927-28	90.3	95.6	—5.3	0.81	—2.0
1928-29	99.7	95.2	+4.5	3.28	+0.6
1929-30	99.5	94.5	+4.9	0.16	—2.6
1930-31	92.9	93.7	—0.8	1.97	—0.8
1931-32	90.8	93.3	—2.5	2.68	—0.1
1932-33	85.9	91.5	—5.6	3.55	+0.8
1933-34	97.7	91.5	+6.2	6.54	+3.7
1934-35	90.4	92.1	—1.7	0.68	—2.1
1935-36	93.0	94.9	—1.9	1.72	—1.1
1936-37	94.8	94.4	—0.4	3.25	+0.5
1937-38	99.5	95.5	+4.0	2.44	—0.4
1938-39	95.3	96.7	—1.4	0.72	—2.1
1939-40	95.7	97.8	—2.2	1.53	—1.3
1940-41	98.8	98.9	—0.1	0.75	—2.0
1941-42	100.1	99.8	—0.3	1.83	—1.0
1942-43	104.6	101.5	+3.1	3.65	+0.9
1943-44	99.9	102.7	—2.8	1.24	—1.6
1944-45	104.2	..	..	2.73	—0.1
1945-46	106.0	..	..	6.58	+3.8
1946-47	67.3	..	..	0.85	—1.9
1947-48	65.0	..	..	1.73	—1.1
1948-49	69.9	68.8	+1.1	..	..
1949-50	68.2	69.4	—1.2	..	..
1950-51	73.5	68.9	+4.6	..	..
1951-52	70.6	68.9	+1.7	..	..
1952-53	62.5	68.6	—7.1	..	
1953-54	69.6	69.9	—0.3	..	..
1954-55	71.8	71.6	—0.2	..	..
1955-56	75.4	..	..	..	..
1956-57	78.6	..	..	..	..

TABLE 5

SHOWING THE CROP STRUCTURE OF PANJAB DURING THE YEARS WITH LOWEST AND HIGHEST SEPTEMBER RAINFALL

	Wheat	Rice	Barley	Corn	Millets	Other food grains and Millets pulses	Sugar-cane	Oil-seeds	Nibore	Condi-ments and spices	Total
Sept. 1907 (*Driest*)											
Actual Acreage ..	7,393,314	695,637	1,359,929	1,157,736	5,018,476	3,550,243	393,727	990,962	1,364,169	30,119	21,964,50
Percent of the total Acreage.	33.66	3.16	6.19	5.32	22.85	16.16	1.79	4.51	6.21	0.15	100
Sept. 1917 (*Wettest*)											
Actual Acreage ..	9,925,795	1,004,691	1,475,341	1,218,553	3,394,402	7,725,162	502,836	1,425,380	1,690,205	35,955	28,388,320
Percent of the total Acreage.	34.95	3.53	5.19	4.29	11.95	27.20	1.77	5.02	5.95	0.15	100

Source : Agricultural Statistics of India : 1907-8 and 1917-18.

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NEWS AND NOTES

NINETEENTH INTERNATIONAL GEOGRAPHICAL CONGRESS STOCKHOLM, 1960

On the invitation of the five Norden Countries, the XIX International Geographical Congress was held at Stockholm from 6th to 13th August, 1960, together with the 10th general assembly of the International Geographical Union. It was attended by over 1,700 delegates from 64 countries. The largest number was from the U. S. A. (401), followed by Sweeden (210), U. K. (146), France (100), Soviet Union (100), Federal Republic of Germany (90), Italy (79), Democratic Republic ofGermany (32), Canada (50). Pakistan was represented by Prof. Kazi S. Ahmad of the University of the Panjab and Prof. Nafis Ahmad of the University of Dacca.

The opening ceremony was held on the 6th August in the Congress Hall Folket's Hus (People's house) under the presidentship of Prof. Hans W. Ahlmann, President of the International Geographical Union. The opening address was made by Governor Rickard Sandler, President of the Swedish National Committee of Geography. The President on behalf of the International Geographical Union and the Organizing Committee welcomed the participants of the Congress. He was followed by an illustrated lecture on " Stockholm, Structure and Development " by Prof. William Olsson of the Stockholm School of Economics.

On the following days the Congress split up into the following sections, to which papers were contributed :

Polar and Sub-polar Geography.
Geographical Cartography and Photogeography.
Climatology and Hydrography.
Oceanography and Glaciology.
Geomorphology.
Biogeography.
Human Geography.
Economic Geography,
Methodology and Bibliography,
Applied Geography.

Meetings were also held of the following Commissions which had been set up earlier by the Congress :

Bibliography of Ancient Maps,
Karst Phenomena,
The Evolution of Slopes,
Medical Geography,
The Library Classification of Geographical Books and Maps,
The Arid Zone,
Periglacial Morphology,
National Atlases,
Erosion Surfaces around the Atlantic,
Coastal Sedimentation,
Applied Geomorphology,
A World Land Use Survey,
The Teaching of Geography in Schools,
A World Population Map,
Humid Tropics.

For the first time regular papers were contributed to these Commissions as in the case of sectional meetings.

About 680 papers were presented, the abstracts of which were printed in the Abstracts, but only 365 were included in the programme. U. S. A. contributed the largest number of papers to the Sectional meetings (67) followed by Soviet Russia (62). Pakistan presented the following 5 papers :

Kazi S. Ahmad ..	Reclamation of waterlogged and saline lands in West Pakistan.
Kazi S. Ahmad and Mr. Mubashir L. Khan.	Variability of rainfall and its bearing on agriculture in the arid and semi-arid zones of West Pakistan.
Kazi S. Ahmad and K. U. Kureishy.	Growth of Settlements in West Pakistan.
Nafis Ahmad ..	The Industrial Landscape of the Dacca Urban Area (East Pakistan).

Nafis Ahmad .. Some Aspects of Rural Land Use and its Mapping in East Pakistan.

A map exhibition was arranged in the Norra Latin School which included International exhibit of Themebic maps, International exhibit of International Atlases and modern Swedish maps. There was an exhibition of Swedish and foreign manuscripts at the Royal Military Record Office, Cadastral Plans and old maps illustrating the development of the Swedish Cultural Landscape 1630—1960 were exhibited at Swedish Land Survey Board.

There was international exhibition of Population Maps at the Stockholm School of Economics and Stockholm Town Planning Exhibition at the Town Planning Office.

During the Congress, there were several conducted local tours, sight seeing boat trips and delightful social functions including the receptions by the Mayor of Stockholm at the Town Hall, and by the British, Japanese, Russian and U. S. A. Embassies, and a farewell banquet at the Town Hall. At the Reception of the Russian Embassy, President Ahlmann was presented a gold medal of the U. S. S. R. Academy of Sciences.

Excursions and Symposia were arranged both before and after the Congress. Symposia were held in different countries on :

(*i*) Agrarian Geography (Denmark).
(*ii*) Physical Geography of Greenland (Denmark).
(*iii*) Nature and culture of the Fjord (Norway).
(*iv*) Northern Norway : Nature and Livelihood (Norway).
(*v*) Fluvial Morphology (Sweden).
(*vi*) Expansion and Retreat of Rural Settlement (Sweden).
(*vii*) The High Mountain Region, Glacial Morphology and Periglacial Processes (Sweden).—Before the Congress.
(*viii*) Coastal Geomorphology (Denmark).
(*ix*) Urban Development and its effects (Denmark).
(*x*) Problems of Urban Geography (Sweden).
(*xi*) Morphogenesis of the Agrarian Cultural Landscape (Sweden)—after the Congress.

Prof. Kazi S. Ahmad attended the Symposium on Agrarian Geography. Excursions were arranged for the field study of :

(*i*) Regional Geography of Denmark.
(*ii*) The coast and archipelago of south-western Finland.
(*iii*) Iceland's Geomorphology.
(*iv*) Spitsbergen Glaciology, Physical Geography, Geology.
(*v*) Deglaciation of South-east and south-east Central Norway.
(*vi*) Rural Settlement in Norway. Types and History.
(*vii*) Glacial Morphology and Inland Ice Recession in Northern Sweden.
(*viii*) Glaciology.
(*ix*) The Karsa Glacier and the Morphology of its Surroundings.
(*x*) From the Plains of Middle Sweden to the High Mountains.
(*xi*) Economic and Regional Geography of Middle Sweden.
(*xii*) Regional Geography of Southern Sweden : The Plains in South-east Sweden.
(*xiii*) Regional Geography of Southern Sweden : Coast and Plains of south-west Sweden.
(*xiv*) Regional Geography of Denmark.
(*xv*) Physical and Human Geography of Finnish Lappland, especially Agriculture at the Limit of Permanent Settlement.
(*xvi*) Regional Geography of the Finnish Lake Plateau and of Eastern Finland.
(*xvii*) A General Tourist Trip through South-western Finland.
(*xviii*) Fjord Land and Coast Land of Western Norway.
(*xix*) Rural Settlement in Norway, Types and History.
(*xx*) Finnish Lappland, North Cape Norwegian Coast.
(*xxi*) Regional Geography of Southern Swedish Lappland.

(*xxii*) Mountains, Rivers and Forests in Central Norrland.

(*xxiii*) Regional Geography of Southern Sweden.

Some of these had to be dropped for want of suitable number of members.

Prof. Kazi S. Ahmad was a member of excursion No. (*xvii*) and Prof. Nafis Ahmad of No. (*xvi*).

The General Assembly meeting was held on the 13th August in which Prof. Carl Troll Rektor of the University of Bonn was elected as the next President and Prof. Hans Boesch of Switzerland was reelected as Secretary-Treasurer. The following were elected as Vice-Presidents :

Hans W. Ahlmann (Sweden 1st. Vice-President).

Chauncy D. Harris (U. S. A.).

Fumio Tada (Japan),

Hassan Awwad (Morocco),

K. B. Cumberland (Newzealand),

I. P. Gerasimov (Soviet Union) and

Pierre Monbeig (France).

Eleven new countries were admitted to full membership : Australia, Bulgaria, Democratic Republic of Germany. Guinea, Iran, Iraq, Malaya, Rumania, South Korea, Tunisia and the Union of South Africa. Hongkong and Singapore were elected as associate members.

The fifteen commissions mentioned above will all be continued for the next four years with only minor changes in the personnel. In addition two new commissions were formed :

A commission on Cartography and a Commission on Economic Regionalization.

The invitation of the United Kingdom to hold the next Congress (1964) there was accepted.

A number of publications were provided free to the delegates of which " A Geography of Norden " edited by Axel Somme and the monograph " Stockholm—structure and development " by Prof. William Olsson may be specially mentioned. Unlike the previous congresses, it is not proposed to print the proceedings of the Congress as a whole.

KAZI S. AHMAD

THE INDUS WATER TREATY 1960

The Indus Water Treaty was signed on September 19, 1960, in Karachi. The signing of the Treaty marks an end of a long standing dispute between India and Pakistan, and opens a new era of water and power development in both the countries on which depends the living of some 50 million people.

Geographical Background

The Indus river system comprises of 6 major rivers—the Indus, the Jhelum, the Chenab, the Ravi, the Beas and the Sutlej and is one of the world's greatest river systems having 170 million acre feet as its average annual flow.

All these rivers rise in the Himalayas and are fed by melting snows and ice and the moonsoon rains.

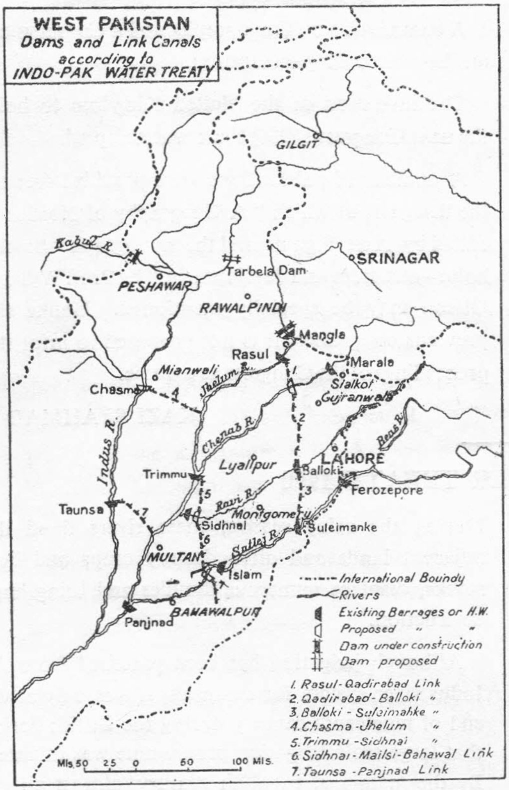
These rivers after descending from the hills enter the Indus Plains, which comprise the greater part of West Pakistan and a part of North-West India. After flowing about half across the Plains they converge into a single streams near Mithankot. During the rainy season, these rivers flood the adjacent lands and often destroy crops and livestocks, displace numerous families and bring huge destruction.

Although irrigation has been practised from the Indus river system for centuries, it was only at the end of nineteenth century during the British period that large scale irrigation programme was initiated. By the middle of the 20th century, almost all the rivers were utilized for irrigation and they now provide one of the greatest irrigation systems of the world.

On the 14th August, 1947, India was divided into two independent countries, Pakistan and Bharat.

The Boundary Commission headed by Sir Cyril Radcliff drew the Panjab Boundary cutting across the Doabs of Ravi and Sutlej, dividing the Sulemanki Headworks and leaving the whole of Rupar and Ferozepur Headworks on the Sutlej in the possession of Bharat.

The Partition of British India gave a very large part of irrigated lands of Punjab to Pakistan and left the important head works in Bharat. So Pakistan overnight became dependent on waters she no longer controlled. The dispute started on the 1st of April, 1948, when India cut off the canal water supplies that entered into Pakistan. Immediately after the stoppage of water, negotiations started with India, however, the supplies were restored but India took a firm stand on the pro-



prietory rights in the waters of the Ravi, Beas and Sutlej. Direct negotiations continued for three years and ended in a complete failure in the settlement of the issue.

Then negotiations under World Bank started. In February, 1954, the Bank proposed that the three eastern rivers, Ravi, Beas and Sutlej would be available for the exclusive use of India, and the remaining three western rivers : Chenab, Jhelum and Indus would be used by Pakistan. The Bank also proposed that the expenditure on the work necessary to replace the supplies of water from Ravi, Sutlej and Beas will be borne by India. In the beginning it was thought that the replacement work would consist of link canals, but detailed studies later on showed that the available surplus flow will not be sufficient to meet all the replacement uses.

The Bank accordingly did some adjustments in May, 1956, and recognised the necessity of storage dams. Then plans were made on both sides in India and Pakistan, and after closer negotiations with the World Bank for another two years nearly, the Bank ultimately formulated the Indus Basin Settlement Plan. After some modifications, this Plan was accepted by Pakistan.

THE TREATY IN OUTLINE

" The preamble to the treaty recognises the need for fixing and delimiting in the spirit of goodwill and friendship the rights and obligations of the Government of India and the Government of Pakistan concerning the use of the waters of the Indus River System.

" The Treaty allocates the water of the three eastern rivers—Ravi, Beas and Sutlej—to India, with certain exceptions specified in the treaty. The main exception is that during a transition period, while the works are being constructed in Pakistan for the replacement of eastern rivers water, India will continue to deliver water to Pakistan from the eastern rivers in accordance with a schedule set out in an annexe to the treaty. The transition period will be ten years, but may in certain circumstances be extended by a further one, two or three years.

" The waters of the three western rivers—Indus, Jhelum and Chenab—are for the use of Pakistan, and India undertakes to let flow for unrestricted use by Pakistan all the waters of these three rivers, subject to Treaty provisions that some of these waters may be used by India in areas upstream of the Pakistan border for the development of irrigation, electric power and certain other uses spelled out in detail in annexes to the treaty.

" Pakistan undertakes to construct, during the transition period, a system of works, parts of which will replace, from the western rivers, those irrigation uses in Pakistan which have hitherto been met from the eastern rivers. India is to contribute to the Indus Basin Development Fund about Rs. 62,00,000 (about $174,000,000) in ten equal annual instalments.

" Both countries recognise their common interest in the optimum development of the rivers and declare their intention to co-operate by mutual agreement to the fullest possible extent.

" Metereological and hydrological observation stations are to be established and the treaty provides for a complete exchange of information from these stations, as well as an exchange of information about proposed river works to enable each party to estimate the effects these works may have on its own situation.

" The treaty sets up a Permanent Indus Commission composed of two Members, one appointed by each Government. The Commission will have general responsibility for implementing the provisions of the treaty and will seek to reconcile any points of disagreement that may arise. Once every five years, the Commission will make a general tour of inspection of all the work on the rivers, and it may, on the request of either Commissioner, at any time visit any particular work in either country. The Commission will report at least once a year to both Governments. Each Government undertake to give the Commissioner of the other Government the immunities and privileges extended under the U. N. Convention on Privileges and Immunities.

" Where differences or disputes cannot be resolved by agreement between the Commissioners, the treaty establishes machinery for resort to a " Neutral Expert " (who is to be a highly qualified) for a final decision on technical engineering questions and for resort, in certain circumstances, to a Court of Arbitration.

" The treaty has nine Annexes. The principal matters covered in these Annexes are : Agricultural use by Pakistan of water from the tributaries of the river, agricultural use by India of water from the western rivers ; generation of hydro-electric power by India on the western rivers ; storage of water by India on the western rivers ; appointment and procedure of Court of Arbitration and transitional agreements relating to deliveries of water to Pakistan from the eastern rivers during the Transition Period ".

THE INDUS WORKS PROGRAMME

"The division of waters provided for in the Treaty necessitates the construction of works to transfer water from the three westren rivers to meet the irrigation uses in Pakistan hitherto met by waters from the Three Eastern rivers. The effect of transfer will be eventually to release the whole flow of the three eastern rivers for irrigation development in India. The systems of canals and reservoirs that will actually be constructed will, however, provide further substantial irrigation development, and will develop important hydro-electric potential in both India and Pakistan. It will also make a much needed contribution to soil reclamalion and drainage in Pakistan, and provides a measure of flood protection in both countries.

"The Programme will be the largest of its kind, to be undertaken any where. Its total cost will be approximately the equivalent of $ 1,070,000,000 (or £ 380,000,000 sterling) of which approximately $ 870,000,000 (or £ 310,0000,000 sterling) will be spent on works in Pakistan and approximately $ 200,000,000 (or £ 70,000,000 sterling) on works in India. It calls for the excavation of about 700,000,000 cubic yards of earth and will require the use of 2,00'000 tons of cement, 250,000 tons of steel and 1,000,000,000 bricks and tiles."

DESCRIPTION OF SETTLEMENT PLAN IN PAKISTAN

The Settlement Plan which includes the construction of two storage dams, 7 link canals, five barrages and a system of tubewells will be financed by the Bank under a special fund called the " Indus Basin Development Fund ".

On the basis of the latest estimates prepared by WAPDA, the Indus Basin Settlement Plan is expected to cost about $1,297 millions, out of which foreign exchange element is about $749 millions.

The Indus Basin Development Fund is contributed by the United States, United Kingdom, Canada, Germany, Australia and New Zealand. India will contribute a fixed sum towards the cost of replacement works.

A BRIEF DESCRIPTIONS OF THE PROJECTS AND THE PROGRESS OF WORK

1. Mangla Dam Project

(a) Description

Mangla Dam Project is a Multi-purpose project designed to conserve and control the flood waters of river Jhelum and to produce cheap Hydro-electric power from the storage water released for irrigation purposes.

(b) Basic data

Length at top ..	11,000 ft.
Maximum Height (Stage I)	370 ft.
Maximum Height (Stage II)	420 ft.
Gross Storage (Stage I)	5.3 M. A. F.
Area Submerged ..	68,000 Acres.
Families displaced ..	17,300
Contents of Dam ..	75,000,000 Cu. Yards.
Initial Power Installation	300,000 K. W.

(c) Progress

The preliminary investigations and designs have been completed to an extent of about 90%. Large scale borings have been done and all the necessary mapping has been completed. Most of the other necessary tests have also been completed. The preliminary geological investigations and mapping has been done, the necessary engineering designs and specifications have also been completed. Construction work on the site would start by January, 1962. The Project will be completed by end of 1968. The total amount spent on this project upto the end of September, 1960 is Rs. 81 million or $ 17 million, and the overall progress on this project is about 3.6%.

2. Tarbela Dam Project

(a) Description

Tarbela Dam will be located on the Indus River in the vicinity of Tarbela village of District Hazara. This project is still in the investigation stage and 3 different sites are under consideration. The planning for this dam is being done for the optimum development possible at the chosen site. A storage capacity of 4.2 M. A. F. is to be financed by the Indus Basin Development Fund and any development beyond this capacity will have to be financed by Pakistan.

(b) Data

Maximum Height ..	350 ft.
Gross Storage ..	5.9 M. A. F.
Contents	98,000,000 Cn. Yards.
Future Power Potential	1,100,000 K. W.

(c) Progress

Detailed investigations at the 3 sites are in progress. The preliminary engineering designs and estimates for these sites are also in progress. After the best site is selected, more detailed investigations will be carried out at that site. It is expected that the designs and specifications will be completed in 1962, and the construction work on the site will start by January 1964 and the project will be completed by Mid 1970.

Total amount spent on the project up to the end of September, 1960, is $ 2.2 million.

3. Link Canals

(a) Description

Seven new inter-river link canals have to be constructed under this Plan. The total length of the link canals will be about 390 miles involving an excavation of approximately 345 million cubic yards and the construction of several hundred bridges and other canal structures. The capacity of these canals will vary from about 6,500 cusecs to about 22,000 cusecs.

(b) Progress

The preliminary investigations and surveying of all the links is proceeding simultaneously, though such work is *nearing* completion on the first link (Trimmu-Sidhnai). It is expected that the work on the site will start by October, 1961. The initial planning work for the next link will be ready at an interval of a few months and it is expected that the work on the last link will start by January, 1964. First two links will be completed by early 1965, and the last by mid 1969.

The total expenditure on link canals upto 30th September, 1960 is $ 1.3 million.

4. Remodelling of Existing Links

(a) Description

The existing links namely the Bambanwala-Ravi-Bedian-Dipalpur link, the Balloki-Suleimanki link and the Marala-Ravi link were constructed by the Irrigation Department several years ago. Large scale remodelling and construction of additional Cross-Drainage facilities have become necessary on these links on account of repeated flood damages. Large scale remodelling of Marala Headworks has also become necessary in view of the existing silt problem there.

(b) Progress

This work has been allocated to the Irrigation Department and they have completed approximately 30% of the work on links, and the balance will be completed by April 1962. The work of remodelling of Marala Headworks, however, is still in the planning stage and is expected to start by October, 1961, and will be completed by April, 1964. A total amount of $ 3.2 million has been spent on this item up-to the end of September 1960.

The Irrigation Department were required to set up :

(*a*) a separate cell in Irrigation Department for Remodelling ;

(*b*) a separate cell for liaison with WAPDA and its Consultants ;

(*c*) depute a task force to WAPDA to carry out some work on links and barrages on departmental basis.

These cells have not been set up yet, and the work of remodelling, as well as the engineering on new links is suffering on this account.

5. **Barrages**

(*a*) *Description*

The Plan includes the construction of 5 barrages—Mailsi on the Sutlej, New Sidhnai on the Ravi, Qadirabad on the Chenab, New Rasul on the Jhelum and Chasma on the Indus. The Mailsi and the New Sidhnai barrages have the top most priority. These barrages form an integral part of the new link canals, and have to be completed by the time their connected links are completed.

(*c*) *Progress*

It was planned to call for the tenders for the first 2 barrages by early 1961 but as a result of recent visit of the World Bank Team it has become necessary to examine various alternatives at Sidhnai more thoroughly and as such the tenders for these works are likely to be delayed by a few months. It is now expected that tenders for Mailsi will be called towards the end of 1961, and these will be completed by early 1965. The tenders for the other barrages will be called at an interval of a few months between each and the tenders for the last job will be called by early 1964. The next two barrages will be completed by early 1957, and the last by 1969. The total amount spent on barrages upto the end of September 1960 is $ 0.2 million.

6. **Tubewells and Drainage**

Description and Progress

The Plan includes Tubewells and Drainages up-to a total cost of $ 50 million. Extensive field investigations for ground water and soils are already being carried out by WAPDA on a very large scale. It is expected that within a year there will be adequate data available to plan the Tubewells and Drainages forming a part of this scheme. These works have to fit into the overall Plan of WAPDA for fighting the waterlogging and salinity problems in the whole of West Pakistan.

It is expected that planning of this work will be completed by the end of 1961, and the work will start in 1962, and will be completed by 1969.

ANIS AHMAD ABBASI

OBITUARY

Dr. I. R. Khan, Professor of Geography, University of Karachi, suddenly died of heart failure in November last. Dr. Khan was the 1st Indian Professor of Geography in the Sub-Continent. He took his Doctorate from the University College, London, under the direction of Prof. Lyde, in late twenties. He joined the Education Department, U. P. on his return and later Muslim University, Aligarh as the Head of the Department of Geography. After serving it for about 8 years he went back to the Education Department and rose to the position of Director of Public Instruction before his retirement. After that he served in the Middle-East for some time on an assignment from the United Nations and then joined the University of Karachi which he served for about 5 years. He will always be remembered for his pioneer work in Geography. He was an excellent teacher with a genial and affectionate personality. May his soul rest in peace. We offer our heart-felt condolence to Begum I. R. Khan and other members of the berieved family.

I. G. U. NEWSLETTER

The I. G. U. Newsletter can be obtained by all *bona fide* geographers and geographical institutions in Pakistan free of charge from the Secretary, Pakistan Geographical Association, Department of Geography, University of the Panjab, Lahore.

STATEMENT SHOWING YEARLY PRODUCTION OF MINERALS FOR THE PERIOD FROM 1947 TO 1959.

Sr. No.	Name of mineral	Unit of weight Measurement	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Antimony	Ton	..	..	..	..	..	..	..	..	..	156	164	36	152
2	Asbestos	,,	..	..	..	..	..	..	..	..	..	..	..	..	46
3	Barytes	,,	..	..	..	..	..	..	..	..	..	..	..	305	508
4	Bauxite	,,	..	..	..	..	..	..	..	..	1,024	3,000	3,317	1,979	2139
5	Celestite	,,	..	..	..	..	136	431	821	361	437	300	854	457	664
6	Chromite	,,	20,365	17,873	16,922	18,125	17,498	17,426	23,442	21,663	28,401	22,746	16,173	24,049	16,023
7	Coal	,,	3,57,744	2,40,777	3,31,964	4,36,750	5,04,703	6,00,026	5,83,727	5,53,743	5,28,848	6,44,751	5,14,858	5,96,499	7,32,634
8	Crude Oil	Barrel	3,33,944	5,02,365	8,23,552	11,20,873	18,88,160	13,84,671	15,49,427	16,99,852	18,08,960	18,53,099	19,24,694	19,88,109	20,41,847
9	Fireclay	Ton	n.a.	n.a.	6,997	1,980	4,121	6,302	5,298	7,079	8,145	6,100	11,635	11,467	14,400
10	Gas (Natural)	000 Cubic ft.	..	..	..	..	..	..	..	..	15,87,059	10,440,972	15,398,729	19,308,060	22,364,993
11	Gypsum	Ton	15,866	n.a.	14,151	16,659	22,784	29,194	27,527	31,150	28,046	36,200	44,064	66,095	84,952
12	Iron Ore	,,	..	..	..	..	..	..	..	714	175	7,012	23,223	8,097	2,250
13	Lead	,,	..	..	..	..	..	..	..	..	..	..	34	..	331
14	Limestoe	,,	3,41,600	3,46,906	2,79,436	3,03,295	3,43,956	7,02,478	8,78,722	8,19,649	8,86,502	7,56,400	9,13,871	11,19,120	9,25,142
15	Magnesite	,,	..	..	..	..	..	..	..	..	..	..	22	..	396
16	Manganese	,,	..	..	..	..	..	..	..	..	..	..	..	..	29
17	Marble (Argonite)	Tons		..	..	..	..	..	..	..	..	..	832	553	2,796
18	Ochres	Tons	..	..	..	..	..	408	510	628	261	400	411	231	275
19	Saphire	,,	..	..	..	..	..	..	..	..	7.7	..	..	..	..
20	Silica Sand	,,	n.a.	n.a.	1,178	4,905	5,325	4,615	7,717	14,217	9,463	10,500	21,414	19,740	21,611
21	Soapstone	,,	..	..	..	..	..	..	..	..	259	1,100	1,232	1585	2,340
22	Rock Salt	,,	n.a.	n.a.	2,01,413	1,36,628	1,42,116	1,25,348	1,46,175	1,46,968	1,39,786	1,60,916	1,55,659	1,77,601	1,61,933

N.B. The figures in respect of Bauxite, Celestite, Chromite, Coal, Fireclay, Gypsum, Limestone, Ochres, Silica Sand and Soapstone for the year 1956 are provisional.

BOOK REVIEWS

THE WIDE WORLD—A GEOGRAPHY: by Preston E. James, Professor of Geography Syracuse University and Nelda Davis, Supervisor of Social Studies, Prince George's County, Maryland.

Published by the Macmillan Company—New York—1959. The book comprises 536 pages with 165 maps, 6 charts and numerous photographs. There is a glossary and the index.

The book has been prepared to introduce the subject to the general reader and is, therefore, of greater interest to him than it is to the advanced students. The matter has been presented in a good readable form, and the object of drawing a geographical-*cum*-economic picture of the world (in broad outlines) has been achieved with some success. Use is made of a large number of beautiful maps and photographs.

The book is divided into two parts. Part I, excluding the last chapter, is devoted to a brief but systematic story of geographical discovery and exploration covering the entire period from ancient Phoenicians to modern times. The importance of the eastern Mediterranean to various communities inhabiting its shores has been emphasized. Contribution of various peoples to the progress of the subject and their endeavours to find solution to the different geographical problems have been recorded in well balanced and attractive narratives. Ancient Greek, Roman, Muslim and Christian geographical scholars, philosophers, travellers and explorers all find a place in this part. Detailed references towards modern means and methods of exploration and scientific study of the geographical phenomena are also not lacking. The last chapter of this section is reserved for a brief account of the physical side of the subject.

The second part of the book contains a regional study of the various countries of the world. Each country receives, to some extent, attention according to its size and political status. The account of practically every country is preceded by a few remarks on its past political history. However, since much of the space has been taken up by maps and photographs for illustrative purposes, only countries of Western Europe and the Western Hemisphere have been described in some details. The rest of the countries of the eastern hemisphere do not get equal attention of the author. New industrial, agricultural and economic developments which have taken place in these countries have been ignored. There is some doubt if the people of these countries would ever express their satisfaction with a mere incidental treatment of their respective national evils. It would have added more to the value of the book if more material had been included even at the expense of excluding some photographs here and there.

The concluding chapter, which deals in brief with some aspects of the material and political forces that make up the life of states, is followed by a glossary of some geographical terms.

TUFAIL BUTT

THE GEOGRAPHY OF NORDEN, edited by Axel Somme pp. 349, 57 platers, 13 coloured maps and nearly 200 maps and diagrams interspread in the script. (J. W. Cappdens Farlar, Oslo) 1960.

The Geography of Norden, as the editor explains, himself, is the product of the efforts of 13 Norden goegraphers to present their countries to their foreign colleagues. They have been very successful in presenting a systematic study of the region as a whole and of each country. First seven chapters have been devoted to the study of the Norden Region as one unit. First chapter has been written by Frid Joo Isachsen, explaining the basis of Norden unity. The five countries thus grouped as one region have physical as well as cultural unity. Language has been picked up as the most important cultural attitude expressive of the unity. Location and physical features especially glaciation and scenery are other factors and as a result of this, Norden frontiers have been shifting with reference to Germany and Russia. This relationship is quite interesting. This has been followed by a chapter on the surrounding seas which influence the life of the Norden People. Five other chapters are on geology, morphology, climate, plant geographical regions, population and settlement, and a very important chapter on Natural Resources and their uses. Each of the above mentioned chapters has been written by the expert in the field. The chapter on Natural Resources and their uses has been written by Professor Axel Somme, the editor himself, in which he has not only described the major human occupations in the Norden countries but also has mentioned observations on Norden's importance in global economy.

The second and a bigger portion of the book is a countrywise study. Comprehensive articles have been written on each country. Though the account is quite a systematic study yet the treatment of economic geography of each country is of the type that more important aspects have been given priority. This has given a diversity of treatment to each country and the choice has made it an interesting reading.

Coloured maps are excellent both as regards technique and cartography. Photographs are carefully selected.

In all respects it is a good text book.

KANIZ YOUSAF.