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WATER SUPPLY IN THE INDUS BASIN AND ALLIED PROBLEMS

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Water-supply constitutes the most important factor in the national economy of Pakistan, which is mainly based on the produce of the soil. Agriculture supports nearly three-fourths of the working population, and accounts for about 60 per cent of the national income. It shares more than 85 per cent of the value of exports. About 90 per cent of the population is rural.

In West Pakistan about 68.4 per cent of the population consists of dependents and of the remaining 31.6 per cent, 20.1 per cent are employed in agriculture. This constitutes about 63 per cent of the working population. This percentage will be further increased if we add the number of persons who are partly dependent on agriculture.

Out of an area of 198,806,000 acres in West Pakistan, 115,718,000 acres are reported. Of this only 28,860,900 acres are cropped and about 21,660,000 acres are irrigated. The irrigated area thus represents 75.4 per cent of the cropped area. The following figures show the total cropped and irrigated area in West Pakistan by Divisions.

TABLE I

Area—thousands of acres

Name of Division	Irrigated area	Unirrigated area	Total cropped area	Percentage of the irrigated to the cropped area
Peshawar ..	847.4	1514.9	2362.3	35.9
D. I. Khan ..	467.1	1690.9	2158.0	21.6
Rawalpindi ..	1553.7	2105.9	3659.6	42.5
Lahore ..	2762.8	901.9	3664.7	75.4
Multan ..	6340.5	244.8	6585.3	96.3
Bahawalpur ..	3082.6	743.0	3825.6	80.6
Khairpur ..	2528.4	—	2528.4	100.0
Hyderabad ..	3432.7	—	3432.7	100.0
Quetta ..	572.0	—	572.0	100.0
Kalat ..	20.6	—	20.6	100.0
Karachi ..	51.7	—	51.7	100.0
Total West Pakistan ..	21659.5	7201.4	28860.9	75.4

be Seen

It will be seen that in the lower Indus Plain, comprising the Hyderabad and Khairpur divisions and the Karachi Federal area, 100 per cent of the cropped land is irrigated. In the Upper Indus Plain in the Bahawalpur, Multan and Lahore divisions, more than three-fourths is irrigated, while in the remaining part the irrigated area ranges from about one-fifth to two-fifths. The percentage of the irrigated area to the total cropped area varies from region to region with the amount of rainfall and the facilities for irrigation available. The percentage of un-irrigated is very high in the northern sub-montane belt, where the rainfall is normally adequate for one or two crops and other sources of water-supply are limited.

In addition to the cultivated area, about 23,000,000 acres of culturable un-cultivated lands, other than current fallows, are available for cultivation, only if water could be had.

Agricultural possibilities have mainly determined the density of population in an old and industrially and commercially backward country. A comparative study of maps Nos. 1 and 2 shows that higher density of population occurs where the conditions of water-supply are better in terms of irrigation facilities. Densities are also high in areas of higher annual rainfall.

Water-supply thus acquires a great significance for the maintenance of increasing population and its economic prosperity. It is a vital factor in opening new lands and increasing the yields in the old lands. Also, more and more water-supply is required to counter desiccation which may result from the advancing waves of sand from the Thar desert into Bahawalpur and Lahore divisions, under the influence of south-west winds.*

The main sources of water may be classified into: (1) rain and snow (2) rivers and canals, and (3) under-ground water, wells.

Rain.—Rainfall has been the most important source of water-supply as it is available everywhere irrespective of orography and relief. But excepting a narrow strip in the sub-montane of the Himalayas it is generally low and deficient in amount, and is unequally distributed over the country. It is also irregularly distributed through the year as well as within the same rainy season. It is not available precisely at the time when it is required. It is variable from year to year and is liable to failure and serious deficiency. As it mostly takes place in heavy showers, there is a heavy run-off. It is generally concentrated in the summer months when the temperatures are high and evaporation great. All these factors reduce the value of the figures of average rainfall.

In the sub-montane strip of the Himalayas the rainfall is about 30″ (Sialkot 31.83″). From here it decreases south-west to 5″ in the middle of the Indus Plain (Sukkur 3.70″). It then gradually increases to about 8″ near the coast (Karachi 7.7″).

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*According to Wright, desert conditions are steadily advancing north-east, towards Lahore at the rate of half a mile a year. (*Geog. Review*, Vol. 38, 1948, p. 30).

Most of the rainfall is concentrated during the late summer months, July to September, during the prevalence of the S. W. monsoon. July and August are generally the rainiest months over the whole of the Indus Plain. The rest of the year is practically dry except for a small amount, $\frac{1}{3}''$ to $2\frac{1}{2}''$, in winter. The amount and importance of this rainfall increase towards the northern and western parts of the plain. Sialkot has 1″ to 2″ of rain for each of the month from January to August. Bannu in the west has about 1″ to $1\frac{1}{2}$ inches for each month from February to April out of a total of 11.11″. In the lower part of the plain, the rainfall in any of these months is generally less than $\frac{1}{2}''$. Monthly distribution of rainfall is shown in Map No. 3. The amount of winter rains and its relation to late summer rainfall becomes still more significant in western and northern mounatins. As the streams drain into the plain they carry the water of these rains to it. Thus the rainfall in the bordering mountains is important in augmenting the water-supply of the plain below. Excepting the northern sub-montane strip the rainfall in the plain is generally inadequate for agriculture, and water has to be supplied by artificial means. An important aspect of rainfall is that the rains stop before the ripening of Kharif crops and the sowings of Rabi, on account of which irrigation becomes necessary. From the agricultural point of view another very unsatisfactory feature of the rainfall is its variability (see Map No. 4). For most of the central part of the plain the incidence of rainfall varies from 40 per cent to 50 per cent. It is also the driest area of the plain. Variability is the least (less than 20 per cent) in the sub-montane area, where the rainfall is highest. There are years when the rainfall considerably falls short of the normal. Map No. 3 shows not only the monthly distribution of mean rainfall but also the minimum and maximum rainfall during the 20 years, 1934 to 1954. It is evident that even in the north-east sub-montane region of good rainfall there are years when rainfed cultivation needs protection by artificial means. One effect of this variability is the occurrence of frequent droughts or floods. A deficiency of 20 per cent and even less would cause drought in many parts, especially if the rains fail during the sowing season.

The effect of the variability of rainfall on crops varies according to the average rainfall of the area. It is greatest in the sub-montane area where the rainfall is just sufficient to support agriculture and where there is a large rainfed area. In the rest of the Indus plain where the rainfall is so low that cultivation without irrigation is practically impossible, deficiency of rains does not have any significant effect on agriculture. It has, however, important effect on pasture and cattle.

In a region like the Indus Plain, where evaporation in summer is great, the amount of average rainfall is a poor index of its effectiveness. The mean annual rainfall deficiency has been calculated according to Thornthwaite. It is shown in Map No. 5. It will be seen that the deficiency ranges from 10 c.m.

in the south of the Himalayan region to 140 c.m. in the lower Indus valley.

Artificial rain.—Dr. Irving P. Krick, of U.S.A., has been carrying on experiments for a number of years on cloud seeding to increase natural rainfall during storm periods which have proved quite successful, leading to bumper crops, the expenses incurred being but a fraction of the value obtained. As a measure of countering desiccation and augmenting the water-supply experiments were conducted in West Pakistan, amongst other places, at Lahore and Jauharabad in 1954 where the clouds were seeded with salt particles. The results have been quite encouraging. In the Lahore area, in a range of 70 miles downwind, there was an increase of about 49 per cent of the normal rainfall for the month of July and August when the seeding was done. Rainfall also showed an increase at Jauharabad but due to lack of suitable number of rain-gauge stations the result could not be accurately determined.

Conservation of rainfall.—In view of the fact that agriculture in large part of the Upper Indus Plain is still rainfed, conservation of rainwater and prevention of its loss by run-off is an important aspect of water-supply, especially in areas not commanded by canals and wells. The practice of *wat-bandi* (terracing) and levelling is already in vogue but it has to be encouraged on a wider and more organised basis. Arrangement could also be made to collect rain water by the construction of ponds in various parts of the rural area, which could be utilised in lift irrigation. The existence of these ponds will also help in the improvement of ground moisture and this would benefit both arable and pastoral farming.

Snowfall.—The main rivers of the Indus plain rise in the Himalayas from regions of perennial snow. This ensures water supply to a certain extent in the dry season, and plays a significant role in the floods. Snowfall in the mountains is not only an important source of water supply in that region but also for the plains below. Very little work has been done in Cryology in Pakistan. Proper record of snowfall and snow accumulation should be kept for western Himalayas from year to year for estimating river flows in the subsequent dry season and for forecasting floods. The importance of this work can be judged from the fact that in the Indus catchment area over 14415 sq. miles remain covered with snow, and there are 19,877 sq. miles snow covered in all the catchment areas of our main rivers as detailed in Appendix I.

As regards the depth of snow, Eliot[1] in 1901 observed that heights of snow peaks were changing by as much as 100 ft. in the course of a year owing to snowfall. Perhaps he meant that if a snow register was kept on a Himalayan peak it might record fluctuation of 100 ft. in a year. Professor Heske estimates a depth of 30 meters of snow accumulation in the higher Himalayas while Gorrie estimates

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1. Burrard and Hayden, *Geography and Geology of Himalaya Mountains and Tibet*, p. 145.

3 meters only. According to Walker[1] winter rains from cold weather storms play the chief part in snowfall. A more extensive record of winter rains and winds together with temperature data will, therefore, be of great help in the estimation of water available in rivers in the succeeding summer season.

Rivers.—Though most of the Indus plain lies in the arid zone it has been gifted with the presence of a number of perennial rivers, fanning out wide in the north where the plain is broader. They, however, converge into a single stream in the southern part. These rivers have sources and upper courses in mountain regions of high rainfall and permanent snow but on the plain they flow through a region with a scanty rainfall and high summer temperature. As the rivers move on further and further from their sources, evaporation and infiltration continuously decrease their discharge while there is very little addition to it on account of low local rainfall. Again, for a few weeks in late summer, in June to mid-September, the rivers carry too much water with disastrous floods, while for the remaining year there is too little water in them. In the winter months the supply of water is small because precipitation in the mountains is generally in the form of snow. The rivers are fed mainly by the seepage from the catchment area. Rivers start rising with the melting of snows in spring and early summer. Further rise takes place when the monsoon breaks out. The supply of water depends upon the extent and slope of the catchment area, the amount of rainfall in it, and the run-off.

The ten-day normals of the discharge of the principal rivers are detailed in Appendix II.

The following table gives the absolute maximum and minimum discharge of the principal rivers :—

TABLE II

*River Discharge Ever Recorded**

River	Site of discharge	Date	Maximum	Date	Minimum
Indus ..	Attock ..		1000000	—	18000
	Kalabagh ..	12-7-1942	917015	17-12-1936	17304
	Ghazighat ..	7-8-1950	827998	5-2-1941	15836
Jhelum ..	Mangla (above) ..	29-8-1928	760000	9-1-1917	3943
Chenab ..	Marala (above) ..	29-8-1929	718000	25-1-1939	3618
Ravi ..	Madhopur (above)	5-10-1955	650000	—	1300
Beas ..	Pang ..	4-8-1927	46529	7-3-1932	1925
Sutlej ..	Rupar ..		260000		2819
	Ferozepur (above)	15-8-1925	353960	23-3-1932	2651

*Unpublished data obtained by the writer from the Director, Meteorological Department, Government of Pakistan.

1. Burrard and Hayden, *Ibid.*, p. 146.

It will be seen that the chief characteristic of all these rivers is the great fluctuation in their flow between the seasons. The peaks of discharges generally occur in the months of July and August when the snow melts in the high mountains reaches its zenith and combines with monsoon rains of the lower hills. During this period both the hill catchment and the plains are almost saturated from the earlier rains. The minimum discharge takes place when the position is reversed *i.e.*, the high hills are frozen and there is little rainfall in the lower or outer-hills in January and February.

For the proper regulation of water supply there is the question of reducing the flood peaks on the one hand and increasing the water flows on the other. There is the problem of utilizing the enormous quantity of flood water, about 119 million acre feet or more than half of the total quantity which goes waste. Apart from variations of rainfall, reckless cutting of forests and excessive grazing in the catchment areas and consequent soil erosion are important factors in the wide variations of flows. Floods have been more frequent and destructive in recent years. During nine years of independence there have been four floods. This appears partly to be due to the greater recklessness mentioned above and partly to the silting up of the river beds on account of which they quickly overflow their banks. The silting process has been facilitated by the construction of bunds or embankments for the training of rivers.

Heavy run-off in the mountain region and the silting up in the plains are, therefore, two of the main problems to be tackled for the regulation of flow and water-supply.

To increase the water-supply in low periods the run off has to be converted into run-in by reafforestation and restricting bad grazing. The process will automatically reduce soil erosion and the transfer of debris to the plain. The silting up shall be reduced by increase in the supply of water during low flows with the help of measures mentioned above. Necessary dredging should also be done. Though its cost may be high, it cannot be higher than the colossal damage done by the recent floods and which may be expected from those that may occur in future.

Besides afforestation, development of pasture and regulation of grazing supplies in the low water period could be improved by the construction of Delay Reservoirs in the tributary streams and mountain torrents. As such reservoirs will be shallow suitable sites can be easily found where the area is flat and barren. Such reservoirs, besides being cheap and easy to construct, will further improve the water supply by raising the sub-soil water table and thus promoting the construction of wells. These will prolong the water supply into critical periods for kharif harvests and rabi sowings in autumn. Such reservoirs will also greatly improve the water supply of the western sub-montane area both in summer and winter.

The creation of big reservoirs by the construction of dams on the main rivers is a sure step for the regulation of water-supply during the course of the year on the one hand and control of flood and preventing its damage, on the other. This is the only way how all the surplus water could be properly utilized. Such dams are under construction at Warsak on the Kabul and at Mangla on the Jhelum. They have been advocated at Kalabagh on the Indus and Tarbela on the Jhelum amongst the proposals of the World Bank for the resolution of the canal water dispute. It is estimated that the canals that will take off from the Mangla and Warsak dams will be able to irrigate 1,167,000 and 93,000 acres respectively. Such dams will not only resolve the problem of water supply but also that of power by producing cheap hydro-electricity.

Another cheap method of improving water supply would be the diversion of river water to low-lying areas along the banks. This will also reduce the intensity of floods. It will not only promote agriculture but also help in the preparation of nearby culturable wastes for pasture and afforestation. Such low-lying areas can be easily located. It so happens that in both the desert areas of Thal and Thar, depressions exist which can draw off large quantities of water from the Indus. In the Thal there are old deserted courses of the river and many suitable depression in between the sand-dunes. In the lower Indus plain an important depression has been pointed out by Oldham* which runs from Khairpur south-east to Umarkot in Tharparker. It is considered to be an old course of the river Sutlej. Another runs west of Indus from Jacobabad to Manchhar Lake. The Aral stream, a distributary, already connects it with the lake which grows into 300-400 sq. miles when Indus comes into floods but shrinks to 14 sq. miles in the dry season when it is drained back into the river. The diversion of flood water into desert areas will have many advantages. It will stabilize sand, dust-storms will decrease, the silt deposited by the river will increase the fertility of the soil and some areas now lying waste may be brought under cultivation and others may be put under permanent pasture and forests. Because of the limited number of habitations the flooding of these desert areas will present few difficulties.

Very encouraging results have been shown by the two reservoirs constructed in the Bahawalpur Division. One of the storage reservoirs is filled during the flood season by inundating an area of 20 sq. miles to the right bank of the channel known as Desert Channel. The supply is taken back into the canal and utilized at a time when the demand is very keen. The second reservoir is fed from the Bahawal Canal. In the sandy waste where not a blade of grass was growing, a compact block of nearly 2,000 acres of good *shisham* forest has developed. These two reservoirs have been yielding 100% return on investment. In addition, fish culture has brought a substantial revenue to the state. As the reservoirs are essentially meant for storage of water no serious attempt was made for cultivation. It may be mentioned that no substantial silting has taken place so as to reduce the capacity of the reservoirs materially.

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*R. D. Oldham—*Geology of India*, p. 451.

The Thal area offers very good sites for such storage basins. A number of shallow reservoirs can be made parallel to the river. After the cessation of floods the water can be released back into the river. Some of it, which will soak into the ground, will automatically find its way back into the river and also raise the water-table in the area.

Besides the construction of reservoir, flood water can be utilized by flow directly into the fields. For this as much extra supply as possible can be pushed into the existing canals after doing suitable raising and strengthening the banks. The cost will be much less than the benefits to be gained. It has been tried successfully in some parts of Punjab and can be gradually extended to all the canals.

Hill Torrents.—There are innumerable hill torrents throughout the sub-montane belt of the northern and western mountains. They suddenly come into floods following the rains in the hills in their rear but otherwise remain dry. The actual rainfall within the sub-montane strip is, therefore, no index of its water-supply. In the western strip the rainfall is low and the supply of water from the torrents plays an important role in the economy of the people. There is property in water and many quarrels are attributed to its distribution. The water is used not only for irrigation but also in filling the tanks for drinking purposes. Pits are dug in the beds of torrents to hold water for drinking after they become dry. Wells are costly to construct.

A large supply of water is available from them in a fairly dry area, and in very short periods even within a rainy season. To catch the water, embankments, sometimes of earth and sometimes of loose stones, are made in the torrent beds a little below the place where a torrent issues from the hills and the water thus held up is led by a system of distributaries to the fields, each of which is surrounded on the four sides by ridges capable of holding.

Permanent reservoirs could be built on more important of these torrents where structure is suitable. The Government has in hand schemes to construct a number of spill weirs for the storage of water.

Sometimes floods in the torrents bring great devastation and villages are swept away. Great damage was done by them in the district of Dera Ghazi Khan last year as well as this year by the breaches in their bunds or embankments.

Canals.—Map No. 6 shows the total cropped area and percentage of irrigated area to total cropped, including sources of irrigation. Canals are the chief source of water-supply for irrigation purposes throughout the Indus Plain. The area commanded by them is shown on Map No. 1. Where water-table is low, the entire irrigation is done by canals. In the upper part of the plain on account of the unfailing supplies of water from snow-fed perennial rivers, and even surface, there has developed one of the most magnificent system of canals in the world. There is a large quantity of water available in rivers during the monsoons. In the early cold weather the saturated hills gradually give up their moisture thereby maintaining the supply, and the winter rains usually supplement this source. When the hot weather approaches there is a rapid increase in the supplies which lasts till the end of the moonsoons.

The distribution of water has been considerably facilitated by the orography of the country. The water is easily led on to the crest of the Doab uplands (known as the Bar) from which it is easily taken down the land. The canals fall into three categories, (1) inundation canals, (2) perennial canals and (3) non-perennial canals.

The inundation canals are the oldest works, and most of them date back to pre-British days. They are in operation during the rainy season when the river from which they take off is in flood. The depth of water in the canals during the inundation is generally 5 to 8 ft. according to the depth of their beds. Waterings are irregular and infrequent. They generally commence to fill with water about the end of April or beginning of May and run dry about the end of September or middle of October. During the earlier months before they rise, lift irrigation is practised. The principal of these canals belong to the rivers Indus, Jhelum and Chenab. The possibility of opening new inundation canals, even of short lengths, may be explored.

The perennial canals derive their supply from the river across which a weir has been constructed to hold up water during the winter, which ensures a permanent supply of water.

The non-perennial canals include those canals to which supply of water is available during the summer and monsoon seasons though they are closed during winter for want of water. Some of the canals of the Sutlej Valley Project belong to this category. Particulars of the principal canal system are given in Appendix III, and those of new projects in Appendix IV. Of the new Projects particular mention is to be made of the (*i*) Marala-Ravi Link. (*ii*) Balloki Sulemanke Link and (*iii*) Bambanwali-Ravi-Bedian Link. Apart from irrigating and feeding the canals in the way, they are also meant to meet the shortage of water in the canals of the Pakistan section of the Bari Doab. Bambanwali-Ravi-Bedian Link is proposed to be extended further to feed the Dipalpur canal which takes off from the Sutlej at Ferozepore which is now in India. There is, however, very little surplus water available for transfer. After the completion of Taunsa and Guddu Barrages all the natural flow of Indus as well will have been fully utilized.

Apart from these new schemes, it is necessary that the water available at present should be more judiciously and equitably distributed. Water should be put to the best possible use and losses of water in transportation should be reduced to the minimum possible. A change from the present system of charging for water, according to the area irrigated, to a volumetric system would probably result in a great saving of valuable water in a critical period and would increase the duty of water.

Canal Water Dispute. Lack of space in this paper precludes the full analysis of this dispute. But as it has a great bearing on the water supply it may be briefly stated as follows.

When Pakistan came into existence in August 1947, Radcliffe demarcated a boundary which runs across the Sutlej and Ravi rivers and cuts across the irrigation system based on these two rivers. India has, thus, a physical control of the upper courses of the rivers and of the headworks located there, together with the water of the canals taking off about these headworks. The flow of water in the canals running into Pakistan is accordingly regulated by India. The canals affected by the partition lie in the Central Bari Doab and Bahawalpur and are connected with the Upper Bari Doab canal on the one part and the Sutlej Valley Proiect on the other. For the distribution of water Radcliffe in para 8 of the award observed that :—

"I am entitled to assume with confidence that any agreement (existing) at the time of Partition as to the sharing of water from these canals or otherwise will be respected by whatever Government hereafter assumes jurisdiction over the Headwork concerned."

This observation was in accordance with the principle of equitable distribution in International Law adopted under numerous International treaties. India, however, thinks that she has the ownership of water as the rivers pass through her territory. Water has accordingly been reduced or stopped on various occasions from flowing into the Pakistan section of the canals to the great detriment of crops in Pakistan. A solution of the problem is being explored under the auspices of the World Bank taking the Indus Basin as a unit and dividing its waters. The compromise World Bank proposals suggested that the flow of the three western rivers, the Indus, Jhelum and Chenab, should be for the exclusive use and benefit of Pakistan, except for an insignificant amount of the Jhelum used in Kashmir. The entire flow of the three eastern rivers, Ravi, Beas and Sutlej, would be available for the use of India, except for a specified transition period which would allow for Pakistan its present historic withdrawals of water from the three rivers. The transition period was based on the time needed to complete link canals in Pakistan with the help of India to replace supplies from the eastern rivers. The latest proposals (June 1956), called the Master plan, include, besides the laying out of link channels, the setting up by Pakistan at India's expense big dams on the Jhelum and at Tarbela and Kalabagh on the Indus with a total capacity of about 15 million acre feet of water to be utilized in times of scarcity.

UNDERGROUND WATER RESOURCES

A portion of rain water percolates into the ground, depending upon the porosity of soil and the nature and amount of rainfall. There is very little run-off in the middle and the lower parts of the plain where the rainfall is less than 20″. In the sub-montane northern belt, where the rainfall is higher, the run-off is also heavier. But percolation from the adjacent Himalayas raises the water-table in its neighbourhood. The geological structure of the north-eastern part of the Punjab plain favours the accumulation of a large amount of water underground. There is a subterranean ridge running south east from Shahpur to Delhi, lying across the normal flow of sub-soil water. Against this subterranean obstruction a large amount of water should be held up underground with a more or less artesian conditions.

The water table should be generally high in the north east of the ridge and low to the south-west of it. The actual depth of water-table should also vary from place to place on account of orographical differences, the central portions of the *Doabs* (interflows) rising into an upland region known as *bar*.

There is another region of high water-table in the middle section of the plains where the water of the rivers draw closer together and percolation is heavy and towards which there is also an underground flow of water. Another subterranean ridge has been located in this area against which the underground flow is piled up. Besides this in riverain and canal lands percolation from them raises the water-table along the banks, and in many areas it has caused water logging. The prospects are thus bright for the exploitation of the underground water resources. They should be adequately developed to the benefit of the dry and thirsty plains.

The Government of Pakistan, with the help of F.O.A. (ICA) have initiated a comprehensive survey of ground water resources in the Punjab. This survey, when completed, will provide necessary information for the exploitation of the sub-soil water for irrigation.

Wells.—Well is a very important old method of water-supply where water-table is at an economic depth and the water otherwise is not unsuitable. They fit in admirably well with the agricultural system, which has been based on separate family groups, and their liking for self-sufficiency. A well is a very practicable and efficient means of water-supply as the farmer has the power to use water whenever he wants it. Wells can play an important part to supplement the flow irrigation as well to supply water to areas beyond its limits. The construction and use of a well, however, depends upon the depth and amount of ground water. The irrigating capacity of an ordinary well may be increased by insertion of tubes from the well floor to tap the lower strata, where geological conditions are suitable. Experimental wells may be constructed to demonstrate the utility of such wells.

Tube Wells.—The construction of tube-wells topping the deeper sources of ground water is intimately connected with the availability of cheap power. A tube-well commands 300 to 350 acres of land per annum and irrigation by it is cheap than by bullock-power lift from ordinary wells.

The development of hydro-electricity in the Punjab in recent years has encouraged the construction of tube-wells. There is a great scope for this method of irrigation in areas uncommanded by flow-irrigation where the sub-soil water-table is reasonably close to the surface, say, about 25 ft. from it. Even in canal-irrigated tracts there are isolated tracts or uncommanded land some of which could be irrigated by tube-wells. Besides, they are good substitutes for canal irrigation in areas liable to be water-logged through flow-irrigation from canals. They can also supplement the canal irrigation during the period when the canals are closed. This is a very important aspect these days when the Pak canal system is faced with shortage of water. But tube-wells cannot be depended upon as a permanent source of supply on account of possible depletion of underground water-supplies. The

Ground Water Development Organisation proposes to construct hundreds of tube-wells. The Punjab tube-well projects include the construction in (*i*) Bari Doab zone, (*ii*) Bambanwali Ravi Link zone, (*iii*) Lower Chenab zone, (*iv*) Upper Chenab zone, envisaging the installation of 2,000 tube-wells of average capacity of 3 cusecs each on the basis of anticipated groundwater supply. While the primary consideration of the project is to reduce water-logging, the operation will also supply water for irrigation. The tube-wells will supply irrigation facilities to 1,812,848 acres. The Rasul Tube-well project includes the construction of 1,860 tube-wells for reclaiming about 30,000 acres of water-logged land. Out of this about 1,500 wells have already been sunk. The possibility of the setting up of wind-mills for power may be explored in areas where water-power is not available, particularly in the Lower Indus Valley where winds are quite steady.

APPENDIX I

Hydrological Data of the Catchment Area of the Rivers of the Indus plain

RIVER	ENGTH IN MILES		Average slope in feet from the source to 1000 feet contour	Catchment area in sq. miles above 1000 ft. control	Area under glaciers (in sq. miles)	Mean annual rainfall in the catchment	Percentage run off of rainfall	Run-off in acre feet	Total discharge of water in one year. (Estimated)*	Ratio of discharge to area taking that of Ravi to be unity*
	Upto 1000 feet contours	Total length								
1	2	3	4	5	6	7	8	9	10	11
Indus ..	1100	1830	15	103823	14415	17.74	77.98	87,355,000	9.0	0.3
Jhelum ..	400	430	37	13030	142	42.33	84.93	23,860,000	5.5	1.3
Chenab ..	380	640	40	10588	1475	47.24	81.06	23,277,000	5.5	1.6
Ravi ..	130	420	115	3123	100	39.00	40.89	6,541,000	1.0	1.0
Sutlej ..	560	900	30	18554	2468	19.71	56.67	13,938,000	3.5	0.6
Beas ..	250	250	48	5663	277	56.50	77.34	12,546,000	2.5	1.3

*Taking the Ravi discharge as unity, the numbers do not represent any actual units of measure but show the ratio of river discharge to that of the Ravi. These are based on short observations and rough estimates.

Source: (1) Hyden and Burrard, *Geography and Geology of Himalaya Mountains and Tibet*.

(2) Gorrie, R. M., *Soil and Water Conservation in the Punjab*, 1946.

APPENDIX II

Ten-Day Normals (1941 *to* 1950) *Discharge of Main Rivers at Selected Sections*

	INDUS		JHELUM		CHENAB			RAVI		SUTLEJ	
	Kotri	Sukkur	Rasul	Mangla	Marala	Trimun	Panjnad	Balloki	Sidhnai	Islam	Adam Wahan
January ...	27000	29046	6792	9384	10284	9984	13245	2020	659	2163	380
	22906	32823	3396	8730	10126	9891	7667	2475	1242	2392	693
	17254	3134	420	9962	10743	12363	7123	2778	867	132	724
February ..	10247	31436	7926	1097	13706	8899	8466	1979	812	631	199
	11781	28967	8355	12287	11992	9455	7765	2872	1070	644	197
	10814	33198	879	144	13565	11338	21279	3105	1303	6	10
March ...	12538	32178	15998	23094	18636	14197	8571	2644	1317	981	154
	15884	45984	21946	27289	21032	26399	25585	6331	1289	4	3389
	25720	35381	2175	2874	20568	24040	19657	2929	1212	5	110
April ...	26169	52453	32718	59841	24199	33983	24823	4091	1831	1249	369
	47430	68773	39875	47715	23213	37904	33889	3361	1638	1533	187
	55698	91815	42496	50078	27626	51842	40945	2948	1609	2083	319
May ...	69922	102052	55759	51916	3384	57037	46408	3389	1505	2207	274
	88864	130467	50146	64830	41672	63836	50766	3289	1377	2652	346
	130700	17526	5812	61720	42867	68626	56522	3225	1286	106	35

June ...	124748	149709	53086	53174	4825	61905	47959	2515	862	3205	97
	140346	200119	52555	58895	60041	82333	62535	3542	1370	9800	337
	165640	221398	51748	56876	63996	72721	63301	2862	1142	9501	2076
July ...	196691	280220	57480	51619	87921	108937	80968	6331	1826	184	6680
	240507	36680	57778	56040	92359	130174	137048	13796	6579	8340	20946
	31405	475712	60660	54850	112044	152707	196190	26675	15639	6538	44161
August ...	389566	491327	59073	57546	113512	148258	198807	30569	21875	59039	61276
	439132	507300	58428	50589	99590	150875	204094	35191	29477	80118	72875
	43401	461354	34219	35871	87364	104677	204648	29667	22095	80852	84049
September ...	359646	348385	26242	30243	65965	89324	155019	27304	17433	56041	51604
	237286	229469	24463	29581	63286	623415	102705	19204	14264	36176	30684
	177795	189431	15427	20909	40010	57700	99025	23127	13031	35908	25749
October ...	130457	133100	9049	15970	21496	21467	55007	8351	9613	24753	22714
	68389	76964	5785	12237	15391	11055	17687	3496	2588	3755	3964
	4342	56245	4924	11052	11224	6915	9411	2380	1253	2725	143
November ...	32246	45629	3325	8832	9088	4491	5706	1712	761	1185	433
	24643	39409	1211	7597	7954	3521	4440	1157	550	690	256
	19951	36166	5857	6966	7390	2766	3057	1496	327	496	217
December ...	16589	32793	2868	13013	6929	2378	2467	1050	613	481	189
	13754	31814	424	6909	8052	2878	2234	721	666	458	172
	18166	31105	480	6545	7605	3294	3280	811	473	731	3

APPENDIX III

Statement showing gross and culturable area commanded by the main canals of the Indus Plain.

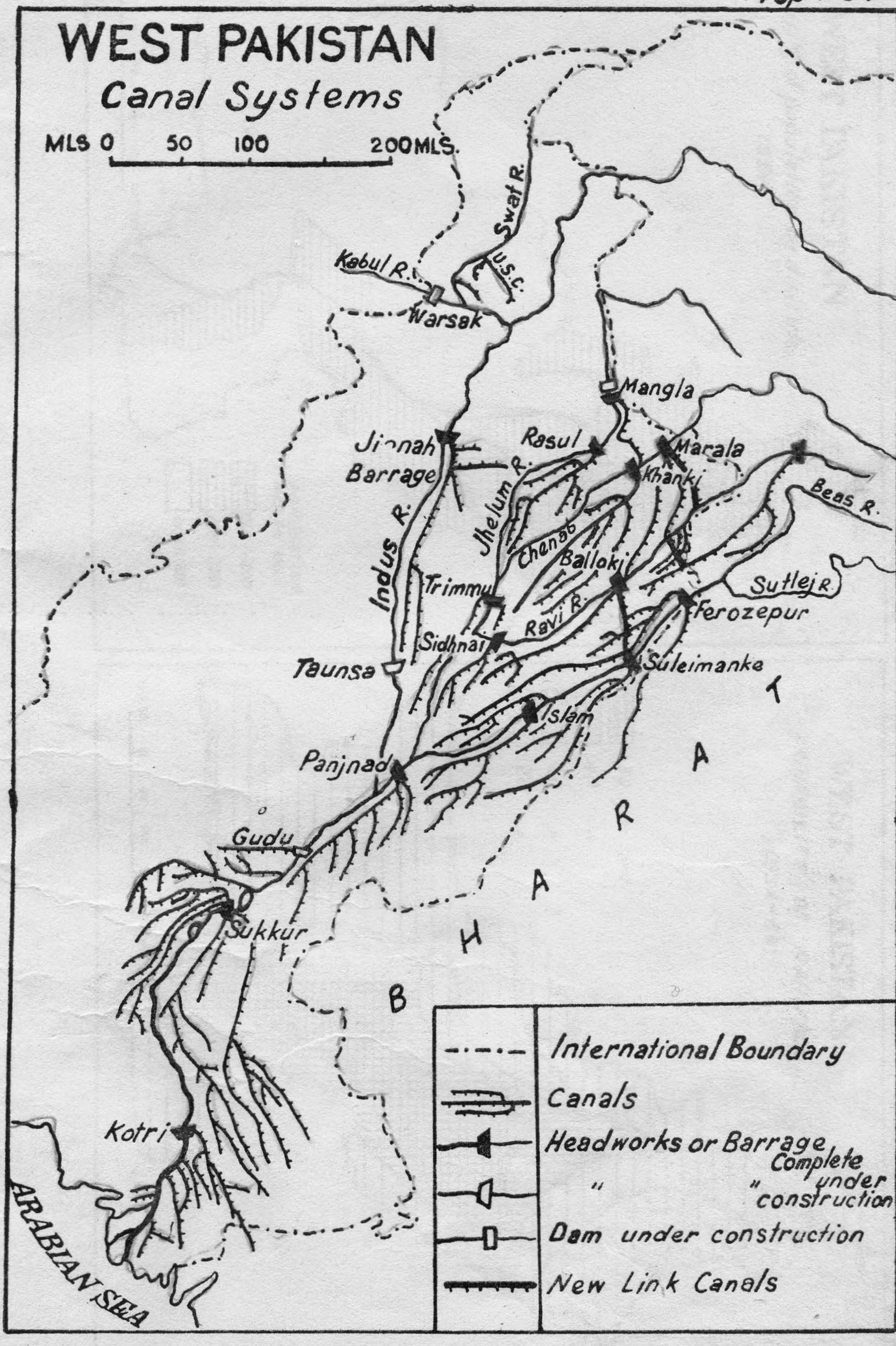
Name of Canal or Barrage		Gross Area	Culturable Area Commanded
Lower Bari Doab Canal	..	1801885	1437826
Upper Chenab Canal	..	1533852	1444992
Lower Chenab Canal	..	3673547	2905999
Upper Jhelum Canal	..	537611	502231
Lower Jhelum Canal	..	1381261	1271890
Pakpattan Canal	..	1395750	1271349
Dipalpur Canal	..	1044060	978823
Mailsi Canal	..	756942	691634
Haveli Canal	..	1116784	1005105
Rangpur Canal	..	341989	329803
Sukkur Barrage	..	..	5000000
Kotri or Ghulam Muhammad Barrage		..	2750000

APPENDIX IV

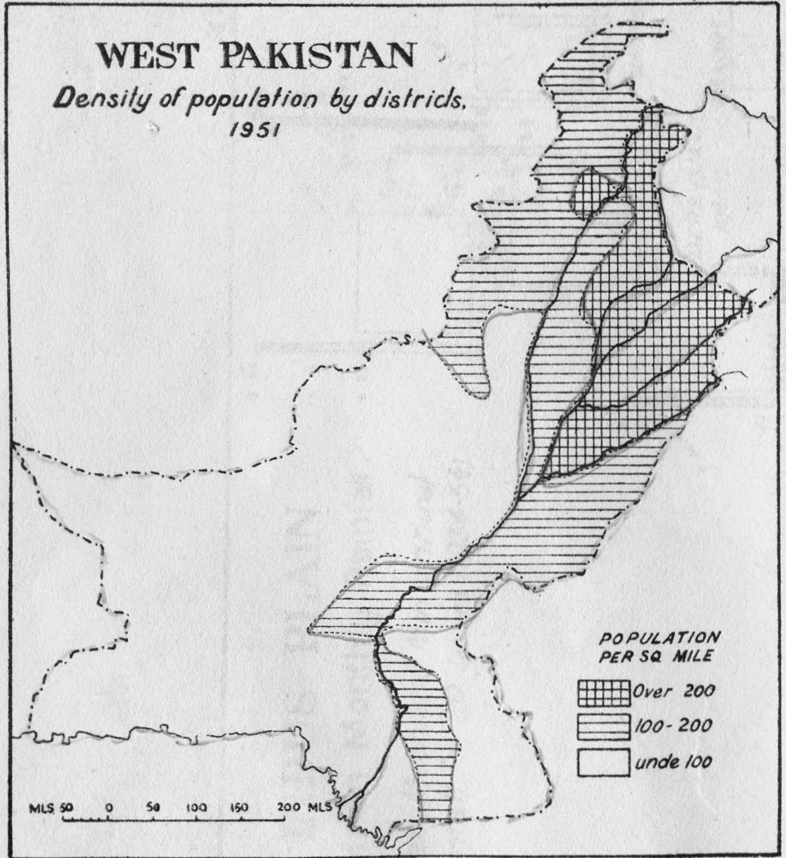
Projects completed or under construction

Project		Estimated Cost (Rs. in Lakh)	Area Commanded (000 acres)	Completion Schedule
Thal Project	..	15,45	11,67	1959-60
Kotri or Lower Sind Barrage		24,00	27,50	1960
Taunsa Barrage	..	10,14	7,10	1957-58
Gudu Barrage	..	28,30	21,44	1958-59
Marala Ravi Link	..	8,52	2,60	1957-58
Balloki-Suleimanki Link	..	7,85	..	1956-57
Abbasia Canal Project	..	3,46	2,60	1955-56
Rodkohi Scheme	..	6	..	1953-54

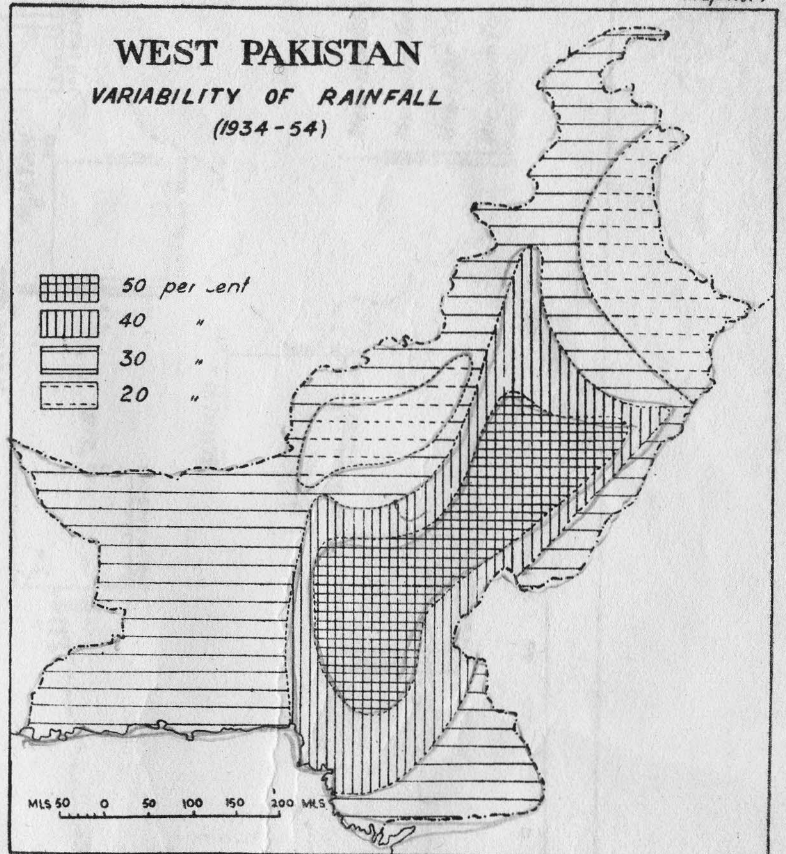
Map No. 1


WEST PAKISTAN
Canal Systems
MLS 0 50 100 200MLS.
Swat R.
U.S.C.
Kabul R.
Warsak
Mangla
Jinnah Barrage
Rasul
Marala
Khanki
Jhelum R.
Indus R.
Chenab
Balloki
Beas R.
Sutlej R.
Trimmu
Ravi R.
Ferozepur
Sidhnai
Taunsa
Suleimanke
Islam
Panjnad
Gudu
Sukkur
Kotri
ARABIAN SEA
B H A R A T
International Boundary
Canals
Headworks or Barrage Complete
" " under construction
Dam under construction
New Link Canals

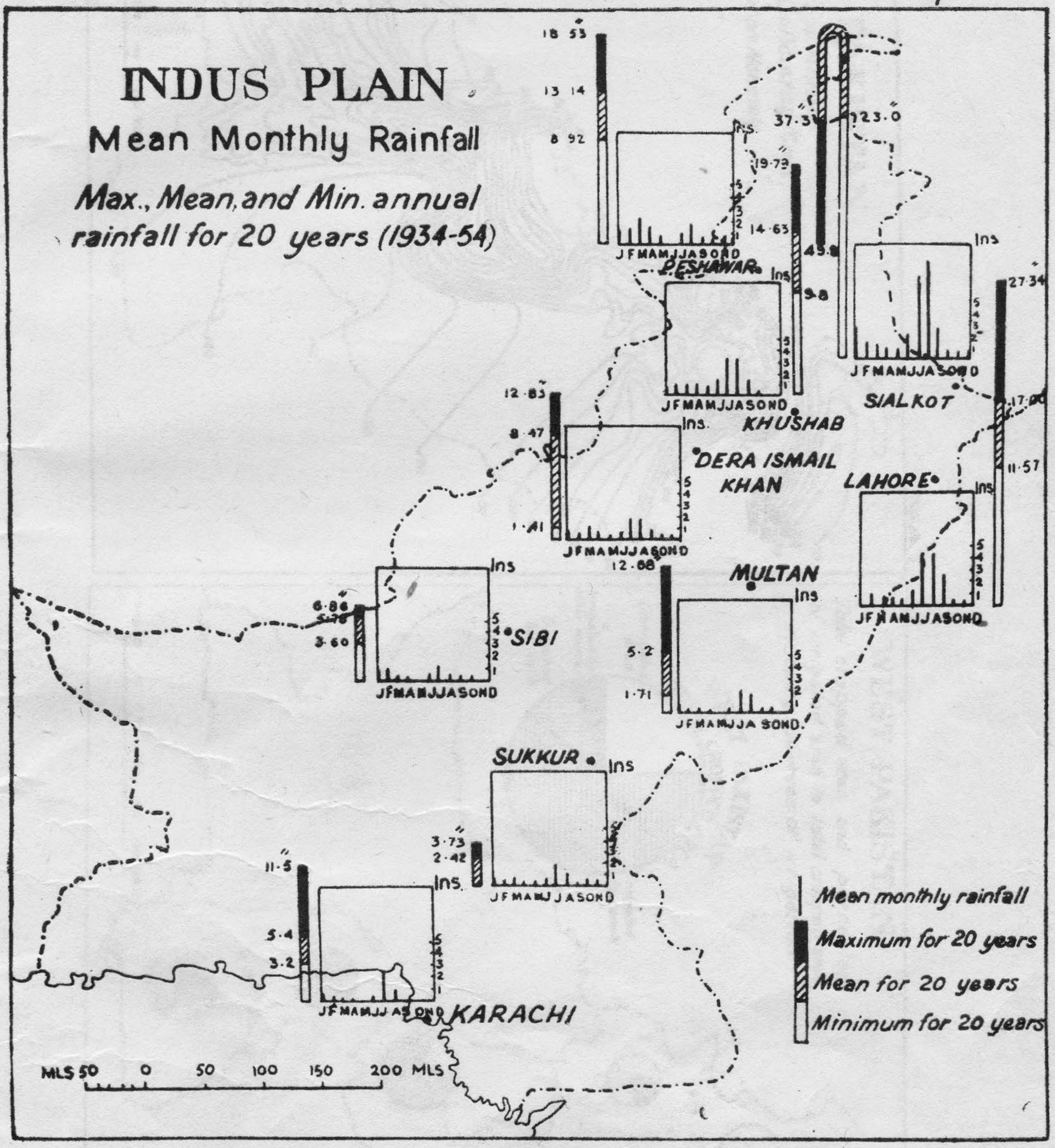
Map No. 2



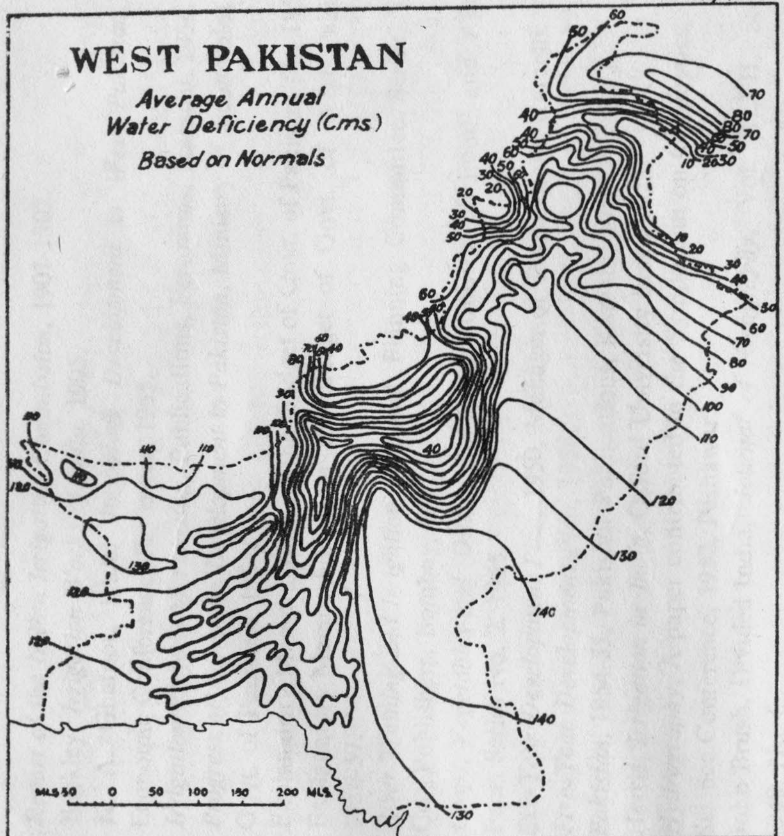
Map No. 4



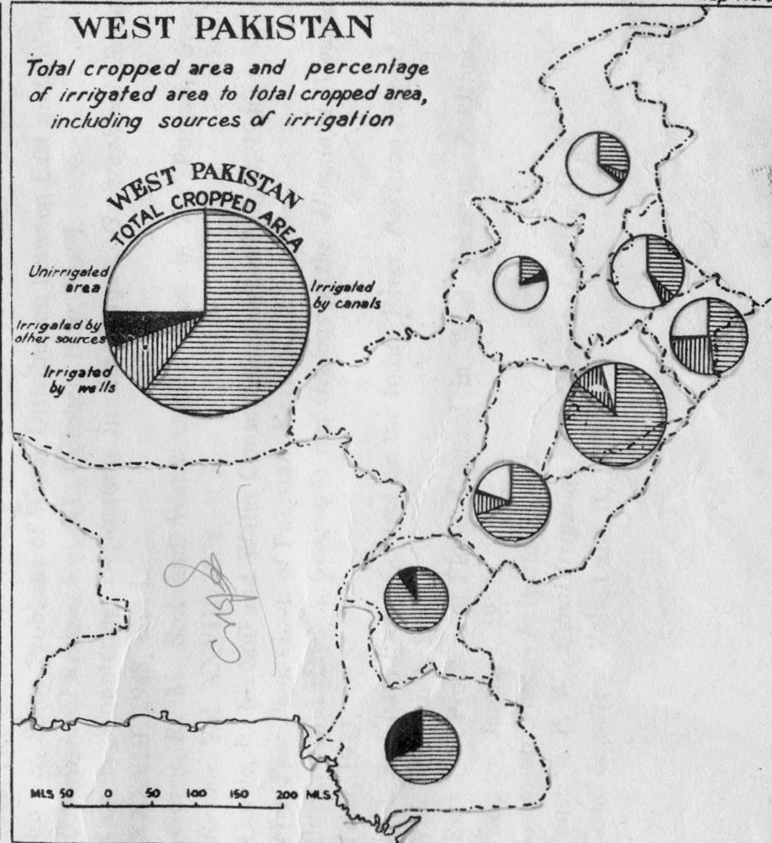
Map No. 3


INDUS PLAIN
Mean Monthly Rainfall
Max., Mean, and Min. annual rainfall for 20 years (1934-54)
PESHAWAR
KHUSHAB
SIALKOT
DERA ISMAIL KHAN
LAHORE
MULTAN
SIBI
SUKKUR
KARACHI
Ins.
JFMAMJJASOND
18.53
13.14
8.92
37.3
123.0
19.73
14.63
9.8
45.9
27.34
17.00
11.57
12.83
8.47
1.41
12.68
5.2
1.71
6.86
5.78
3.60
3.73
2.42
11.5
5.4
3.2
Mean monthly rainfall
Maximum for 20 years
Mean for 20 years
Minimum for 20 years
MLS 50 0 50 100 150 200 MLS

Map No. 5



Map No. 6



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LAND TENURE AS A FACTOR IN LAND-USE IN WEST PAKISTAN

BY

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WEST PAKISTAN lives in villages, and is predominantly an agricultural country. Agriculture engages more than 82 per cent of our population, accounts for 60 per cent of the national income and 90 per cent of our foreign exchange earnings, and provides a major base for industrial development. Obviously, therefore, the problems of land are of greatest importance. Their correct magnitude would be apparent when it is realised that of late years, Pakistan has been spending over 80 crores of foreign exchange on food imports : a disquietening and paradoxical situation. Imports, however, are no remdey for our food deficit, which has assumed a chronic shape and is, to a large extent, holding up developments in other sectors of our economy. Even many of the much-patronised industries, which made a fairly good progress before the food shortages showed themselves, are seriously suffering due to foreign exchange stringency forced by the large-scale food imports. Of the land problems of West Pakistan that of tenure is one of the very vital and of far-reaching consequences.

In the industrialised countries of Europe, America and Asia, people have many sources of income, but in West Pakistan land is by and large the only form of capital. It is on the exploitation and proper utilization of the land resources alone that the entire economic and social structure of West Pakistan rests. The few manufacturing industries that have grown up also owe their existence to the raw materials derived from agriculture. Even apart from that no industrial development is possible without agricultural progress.

Hitherto the tenants of West Pakistan practise a sort of subsistence agriculture with low yields which barely provides for their simple needs of semi-civilised existence. Such an agricultural economy cannot bear the burden of supporting the increasing population and urban growth with its paraphernalia of luxuries and of providing a civilised standard of living. It leaves no margin for improving the standard of living, it gives no protection against lean years, it cannot bear the increasing cost of governmental machinery, the Navy, Army and the Air Force, it cannot finance university and school education, health institutions, and the increasing demands of nation-building programmes. One of the major causes for this impoverished and stagnant state of agriculture is the system of land tenures, which hardly provides any incentive for improvement to landless peasants.

The word tenure is derived from the Latin *tenere*, to hold, and connotes the conditions under which land is held. It may be described as a body of rule which deals with the relationship between two or more individuals with respect to their rights in the use of land and the practice of cultivation and apportionment of produce. But it is not enough to confine land tenures to the bounds of law. In a wider sense it comprehends the whole relationship of man to the soil. This relationship on the one hand transforms the land and on the other transforms the man himself. For this reason, every member of society is concerned with the tenure problems and the tenure situation.

Tenure problems are also important to the society as a whole, to urban people as well as to rural people, for all food and fiber are raised under some tenure arrangements. The form of the tenure affects the way in which the land is used, and quantities of capital and labour employed. Thus, some lands are more efficient than others, and the degree of efficiency in production is, in many cases, a function of the way in which the farmer has access to the rights in the land which he tills. Thus, the tenure problems affect the productive capacity of the farmers and, in so doing, affect the well-being of other members of the society. The tenure forms, however, affect more directly the lives and economic well-being of the agricultural population than of the urban population. The various tenure arrangements under which the land is tilled affect the income and social status of the farmer.

In our present set-up an individual's right to use land must be acquired from someone. It may be acquired by the purchase of, or through the gift of, all or part of another's right for a limited period of time. Tenure problems, therefore, arise from competition of individuals for rights in agricultural land which is limited in supply.

Land tenure discussions frequently centre about the problem of farm tenancy. Significant as it is, the term "tenancy" is more limited than "tenure" and applies only to the leasing or sharing by a tenant of a portion of the rights in land by the owner or landlord. Tenancy represents only one type of tenure relationship and its importance is more than balanced by the problems involved in the acquisition, holding and transfer of ownership rights.

There are wide variations in the conditions under which land is held in West Pakistan. The land may be owned by the Government, land magnates or peasant proprietors. If the land is not cultivated by the proprietor himself, it is held by the tiller under different forms of tenancy. These may be tenants with full right of occupancy, tenants for fixed periods or tenants-at-will. When there is a dual interest in the land, the proprietor receives from his tenant some form of labour, a portion of the crops and cash contribution, and the tenant may or may not have a heritable and alienable right in his holding. But when the land belongs to the state, the tenant enjoys, in practice, all the privileges of a proprietor, subject to rules for prevention o sub-division and promotion of good husbandry.

The systems of land tenures, which are operating in West Pakistan today, have evolved over a period of 150 years or more under the influence of changing political and social forces. The Muslim rulers of India were concerned primarily with the protection of the state from external aggression, extension of territories and the maintenance of law and order inside the state. The wars between different rulers were frequent and the subject played the same role in them as pawns on chessboard. The poor cultivators had to share their defeats and successes. The vicissitudes in the fortunes of the rulers and their people were frequent, and, as the country was torn by wars and strifes, law and order and settled forms of Government had a doubtful existence.

It was under these circumstances that reins of government passed on to the British Crown. The British regime brought to this sub-continent what in those days it needed most, namely, a government invulnerable to external attacks and strong enough to establish the rule of law in the country.

When the British took charge of India, the condition of land tenure, especially in the northern districts, was chaotic. Many villages represented an occupation by conquest, wherein the old landholders were reduced to the position of tenants, and adventurers and their camp-followers raised to the status of landholders. Rack rents were common because the tenure of the landholders being itself uncertain they tried to extort as much as possible from the tenants. In the absence of accurate information regarding the native systems of tenure the British Government, which supposed itself to be cofirming *status quo*, entered into treaties with the so-called local chiefs by which it turned them into landlords entitled to exact rent from their peasants and to dispose of their lands in whatever manner they liked.

But the broad treaties with native rulers were not enough. When the British were faced with the task of detailed administration they found that the rights associated with the holdings of land were indeterminate and difficult to categorise. The judicial and revenue authorities specially found unusual difficulty in forming a clear view of them amidst the complex of social privileges and obligations of which they formed a part. Accordingly, to facilitate their work, the Government directed (*i*) a comprehensive study of customary law, (*ii*) instituted a system of public registration of conveyances, and (*iii*) directed the maintenance of public records-of-rights in lands in rural areas. All this had its origin in the requirements created by the fiscal system inherited from the earlier rulers under which the state derived its chief sources of income from a share in the produce of the soil. Again the higher authorities, which were all British, tried to interpret the native tenure in terms of English law of real property. The result was that in course of time, subject to the overlordship of landlords to which the Government was bound by its previous commitments, treaties, and engagements, the land tenures assumed a definite form and shape which they had been hitherto lacking.

Another main contribution of the British rule was the systematic commutation of the share of the produce into money tax and its adjustment to the ascertained production of different soils and types of cultivation. The land revenue, as the tax was called, was fixed for a sufficiently long period to give security to the cultivators, but was liable to periodic revision in view of changing prices or an alteration in the system of agriculture.

This procedure involved a cadastral survey and preparation of a record after detailed local investigation of the titles of right-holders, who became liable to payment of land revenue. The record of titles, which was thus originally designed to meet fiscal requirements, subsequently acquired a value in clarifying private rights and in giving a sense of security to right-holders.

The system of land tenures has always been determined by the political ideas prevalent in an age or a people. Thus in the Middle Ages, in Europe as well as in Asia, the function of the ruler was the protection of the state from external attacks, maintenance of law and order, and punishment for heresies against the established Church. Therefore, during these ages the system of land tenure was bound up with the ideas of service, and juridical and governmental rights which are compendiously called feudalism.

With the march of times philosophy has dominated the law, the hold of religion has weakened and secularism has caught the imagination of the people of the world. The defence of the state too has been organised not on the feudal principles but on the basis of a standing army raised by the state directly. Consequently, the agrarian feudalism has been gradually finished either through peaceful means or peasant revolts in England, France, Denmark, the United States and most other progressive countries of the world, and peasants have been given tenure rights and rights of inheritance and proprietorship. India too has largely liquidated the landlords and considerable progress has been made in this direction even in East Pakistan. But in West Pakistan the prevailing system of economy is still of large landed proprietors and a subordinate or landless peasantry. The landlords who perform no economic function in return for the produce of cultivation still continue to have their stranglehold.

No agricultural census has been taken in Pakistan and no record of any kind with respect to the distribution of land tenures exists. It is not, therefore, possible to show the much-desired areal distribution of tenures in West Pakistan, and only a general idea of their distribution can be given. In the former province of Sind about 48.6 per cent of the cultivated land is owned by 0.5 per cent of the total owners, in the Punjab about 20 per cent by 3 per cent, and in North-West Frontier Province about 48 per cent of the total cultivated land is held by big landlords. The position in the former province of Baluchistan is, perhaps, worst. About 80 per cent of the total area in the former Sind, 56 per cent in the Punjab, and 50 per cent in the North-West Frontier Province is cultivated by tenants-at-will. Thus the majority of the tenants, throughout West Pakistan, are not secure with regard to their tenure or incidence of rental.

A few, rather half-hearted efforts, have been made by the Government for reforming the land tenure system. But the West Pakistan politics being dominated by big *jagirdars* and landlords, these efforts have been almost defeated by vested feudal interests inside the Government and the *zamindars* at large outside it. A *Raiyetwari* system still persists over most of West Pakistan. The condition of the peasantry is more or less the same as it was in 1947, when Pakistan came into existence as an independent State. But the change from feudalism to peasant proprietorship is a natural process. It is overdue now and cannot be stopped. Popular feeling is developing against the *Zamindari* system and any attempt to delay its liquidation for long is bound to erupt in revolution. The sooner the big estates are broken up and maximum ceiling fixed on individual landholdings and permanent, heritable and transferable rights of possession conceded to the tenants the better for everybody.

The land tenure problem constitutes a mighty challenge to the Government and its responsibility in tackling it cannot be over-emphasised. Political considerations and party affiliations should not be allowed to delay its solution and the completion of the agrarian revolution. For a modern state is nowadays not so much a law and order state as it is a social welfare state. Accordingly one of the most characteristic development of modern political philosophy is seen in the widening range assigned to governmental activities and responsibilities and the evaporation of the doctrine of *laissez-faire*. There may be difference regarding the balance between a state activity and the private enterprise, but there is every where a tendency to assign to the state wider authority and greater initiative as an agency for improving the social standards and economic life of the people and few measures can achieve this objective better and for larger numbers than the evolution of a sound system of land tenure. Therefore, if the West Pakistan Government is found lacking in enthusiasm, the subject of land reforms should be taken over by the Central Government, where the support of the more realistic and non-interested members of the parliament, in this matter, from East Pakistan may defeat any obstruction from the vested interests of West Pakistan and enable the reforms to be pushed through rapidly.

The existence of big estates might have been justified to a certain extent in the past, when the population was not large, the land idle, and the demand upon it small, but there is no justification whatsoever for its continuation any longer. The institution of landlordship, characterised by large concentrations of property, wealth and power, is basically incompatible with the aspirations of modern man and the demands of time, and calls for urgent abolition.

Rapid development of primary production, full utilization and proper conservation of the land resources of the state is usully regarded as involving a choice between two methods, the development of large-scale production through the agency of organisations or individuals having command of adequate capital resources and managerial skill, or alternatively the stimulation of a peasant economy. There is yet another school of thought that holds that this can be best achieved by a system in which the state and the rural community would become partners in exploiting the resources available for primary production. The former would contribute land, capital, mechanical equipment, skilled direction and marketing facilities, and the latter would contribute labour; the produce being shared by the two partners in the ratio adjusted to the interests involved. Those who hold this view have obviously been influenced by the results achieved by the Soviet system of collective farming. Individual holdings of land, however, are not incompatible with cooperative methods of farming and higher production.

In any case, if real good husbandry is to be ensured, if the utilization of the land is to be made more intensive, if the food production is to be raised and if the huge foreign exchange squanderings on food-grain imports are to be conserved for the economic and industrial development of an under-developed region as West Pakistan, the big landed estates, which have dominated rural life and exploited the rural population, must disappear and full ownership in land provided to the tenant. This is the trend all the world over and West Pakistan cannot live in a vacuum. The tenancy laws of the whole of West Pakistan should be consolidated and rationalised on a uniform basis.

SOME ASPECTS OF THE RURAL-URBAN COMPOSITION OF POPULATION IN EAST PAKISTAN

BY

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THE rural-urban composition of the population of a region in its several aspects forms an integral part of demographic studies. The present paper seeks to analyse the rural-urban composition of the population of East Pakistan by economic categories, age and sex, and sex ratio. In the case of the population of East Pakistan, before examining some of the aspects of its rural and urban compositions it would be of use to clarify what is precisely termed as rural and urban. For the purpose of census, all the agglomerations in East Pakistan, whether within a municipality or outside it, with at least 5,000 inhabitants were defined as urban and less than that as rural, with the exception of seven townships which were regarded as urban though they have individually less than 5,000 inhabitants each.

Table 1 is drawn to compare the rural and urban population with respect to the economic categories in East Pakistan. Out of the total population of

TABLE 1[1]

Urban and Rural Population by Economic Categories, East Pakistan, 1951.

Urban and Rural Economic Categories	Population (000)		Percentage of Total Population		
	Total	Urban	Total	Urban	Rural
Population ..	41,932	1,829	100	4.3	95.7
Civilian Labour Force	12,886	677	30.7	1.6	29.1
Agricultural Labour Force	10,715	119	25.6	0.3	25.3
Non-Agricultural ..	2,171	558	5.1	1.3	3.6
Self-supporting Persons not in Labour Force[2]	128	19	0.3	.04	.26
Dependents ..	28,918	1,124	69.0	2.7	66.3
Children[3] ..	15,220	547	36.0	1.3	35.0
Others ..	13,698	577	32.7	1.4	31.3

1. Most of the figures quoted in the article are from the *Census of Pakistan*, 1951. Reference to these figures, occurring in the later paragraphs of the article, is not given.
2. Including Defence Force and persons who are economically inactive.
3. Under 12 years of age.

41,932,000, there were 1,820,000 in the urban areas in 1951. This accounts for only 4.3 per cent of the total population in the cities and the rest, 95.7 per cent, as rural population. It reflects an extremely agrarian nature of the society. East Pakistan, like most of the oriental countries, is rural in character.[1]

In respect to the economic categories in the compositions of rural and urban population in East Pakistan, the same tendency is also found in West Bengal.[2] The Civilian Labour Force in East Pakistan was 30.7 per cent of the total population, out of which extremely high percentage, 29.1 is found in rural areas whereas only 1.6 pei cent is in urban areas. Of course the entire agricultural labour force is rural as reflected from the figures.

Out of the total of 25.6 per cent, 25.3 per cent is in rural areas and only 0.3 per cent in the urban areas. Even out of the non-agricultural labour force of 5.1 per cent, majority are in rural areas, since 3.8 per cent is classed as rural and 1.3 per cent as urban. Self-supporting persons *i.e.* economically inactive population and armed forces are very small in percentage, yet the vast majority of them are in rural areas. A very interesting demographic fact in regard to the rural-urban composition of the population of East Pakistan is the vast proportion of dependent people in rural areas. The census reported, as indicated in the table, that 69.0 per cent of the total population was returned as dependent, out of which 66.3 per cent were in rural areas. The main reason for the concentration of huge dependent population in rural areas are two : firstly, majority of the womenfolk stay in the villages, secondly, more than half of the dependent population is consisting of children. Families generally are large with a number of small children. These children do help on the farms as members of the family units but in effect they are greatly under-employed and have no economic status.

The concentration of the population in rural areas is chiefly due to the politico-economic history and peculiar social conditions of the country. The importance of the study of the rural-urban population in economic categories is that it clearly indicates the relative position of the labour force and other economic characteristics. This study is useful in the analysis of manpower resources and their utilization for future industrial and economic development and planning.

An interesting study of the rural-urban composition of the population is shown in Table 2, which illustrates the male and female populations by age group, of the two principal cities and of the districts in which these cities are located. In the age group 0-9 there is a great preponderance of females in Dacca town as well as in the district. But in the age group 10-39, on the other hand, there is a vast majority of

1. Birender Nath Gangulee : *Trends in Agriculture and Population in the Ganges Valley*, Methuen, London, 1938.

2. R. K. Mukerjee : Economic Structure of Rural Bengal, A Study of Six Villages, *American Sociological Review*, December, 1948.

TABLE 2

Percentage by Age and Sex, Selected Cities East Pakistan. 1951.

Age Group	Dacca				Chittagong			
	Town Male	Town Female	Dist. Male	Dist. Female	Town Male	Town Female	Dist. Male	Dist. Female
All Ages ..	100	100	100	100	100	100	100	100
0-9 ..	18.9	30.6	27.8	30.0	13.4	30.0	27.0	28.6
10-39 ..	63.6	53.7	51.9	51.9	70.1	52.7	55.0	54.8
40-59 ..	14.2	11.6	15.1	13.4	13.0	11.3	13.8	12.4
60-Over ..	3.3	4.1	5.2	9.7	3.5	6.0	4.2	4.2

males in both Dacca and Chittagong towns and near equality in the sexes in both the districts. The explanations for these are very easy. For the age group 0-9, the population is chiefly dependent, it does not matter where they stay and to what sex they belong. But in the age group 10-39 a vast majority of male in the town is mainly due to the fact that they are wage earners in the industrial areas of Dacca and Chittagong who come to the cities to earn their livelihood and leave the women folk in the rural areas due to acute shortage of accommodation. The same is true for the age group 40-59 but not as marked. These are comparatively older people who by virtue of their seniority in services find out some sort of accommodation for their families. Actual increase in the percentage of female in age group 60-over in both the cities and districts is hard to explain. It may be, however, due to the large number of widows in the population of East Pakistan.

Tables 3 and 4 are drawn to compare males per 100 females by population size group in the populations of East Pakistan and the United States. Although the figures are not directly comparable, they are the nearest available. They show, however, that as the size of the population increases, males per 100 females also increase for East Pakistan. But the population size 5,000-10,000 and under 5,000 in East Pakistan have higher proportion of males than the population size 10,000-25,000. In any case, there are more males in the population of East Pakistan. On the other hand, in the United States the sex ratio is smaller in the larger urban areas than the rural areas.

TABLE 3

Male per 100 *Female by Population Size Group, East Pakistan,* 1951

Size of Town	Males per 100 Females
100,000 and Over	.. 171
25,000—100,000	.. 146
10,000— 25,000	.. 127
5,000— 10,000	.. 136
under 5,000 (rural)	.. 146

In the United States there are great job opportunities for women in the urban areas and men are needed to work on the farms. But in East Pakistan the case is just opposite, in fact no job opportunity at all exists for the women.

Table 5 shows the rural population by economic categories in East Pakistan. As it should be expected, there is a great majority of population in agricultural labour force category which is reflected by the figure 26.4 per cent as against only 4.0 per cent

TABLE 4*

Male per 100 *Female by Population Size Group, United States*, 1950

Size of Town	Males per 100 Females
500,000 and Over	97.3
100,000—500,000	94.4
10,000—100,000	94.6
2,000— 10,000	95.8
Under 2,500 (rural)	107.7

*** Source :** Computed from Warren S. Thompson, *Population Problem*, McGraw-Hill, 1953.

for non-agricultural labour force. However, the most significant feature of this economic composition in the rural areas is that there is a great proportion of dependent population, including both children under 12 years of age and others. This aspect of the rural population of East Pakistan is important in the sense that it throws light on the amount of unemployment and under-employment in the rural areas.

TABLE 5

Rural Population by Economic Categories, East Pakistan, 1951

Economic Categories	Total	Percentage
Rural Population	40,113,000	100
Agricultural Labour Force	10,596,000	26.4
Cultivators Land Owning	—	20.0
Cultivators Renting	—	2.6
Landless Labourers	—	3.8
Non-agricultural Labour Force	1,613,000	4.0
Other Self-supporting Persons	109,000	.3
Children	..	36.6
Other Dependents	..	32.7

In general the study of rural and urban compositions in their various aspects are highly important because it gives a clear picture of the many characteristics of the population, which can be usefully utilized for the general purpose of social and economic planning.

A PRELIMINARY STUDY OF THE ATMOSPHERIC TEMPERATURE IN WEST PAKISTAN

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TEMPERATURE is certainly the most important climatic element. No description of a climatic environment can be complete without a notation of the prevailing temperature conditions, especially of its distribution in time and place. Moreover, temperature provides a working condition for all physiological and ecological processes. This is at once revealed by the fact that many and most of the bio-climatic indices are based on temperature. Hence the importance of the study of temperature in the fields of climate, agriculture and biology.

West Pakistan has a great diversity of relief. It has an equally complex physical climatology. The net result of these factors is a very complicated temperature field both on the surface and in the upper air. The present paper is an attempt to analyse the meteorological basis of the temperature conditions in the country. The paper also briefly discusses some of the more important temperature data which are often required to depict the basic climatic characteristics of the country.

The writer wants to make an apology for using different scales of temperature in the paper. It was proposed to use the Fahrenheit scale but owing to the inconvenience in showing the upper air temperatures in this scale, the centigrade or preferably Kelvin scale had to be adopted for temperatures of the free atmosphere.

TEMPERATURE AS A FUNCTION OF THE LATITUDE

Latitude exerts the major control on the temperature of a place, since it determines the amount of solar energy received in the form of insolation. The solar or mathematical climate of a place would, therefore, naturally depend on the balance between the amount of heat received in the form of radiant energy, and lost in the form of back radiation. The studies of Simpson[1] Albrecht[2] Phillips and Baur[3] and many others reveal that there always exists a balance between heat income and outgo so that the planetary temperature 57.7°F (287K) does not show any perceptible variation from year to year. There is, however, a remarkable disparity between the two sides of the account. It has been shown that at low latitudes there is a net gain of heat whereas at higher latitudes the opposite is true. This consequently leads to a heat transfer from regions of heat excess to those of heat deficit.

Table 1 shows the geogrpahical distribution of the effective net heating and cooling of the earth's surface and atmosphere for the latitudes of West Pakistan. The table reproduces the values in units g/cal/cm²/min as given by Simpson, Albrecht, and Philiips and Baur. The figures have been interpolated by the present writer:

TABLE I

Annual means of the incoming and outgoing radiation for the latitudes of West Pakistan

Latitude No.	Simpson			Albrecht			Phillips and Baur		
	1	2	1—2	1	2	1—2	1	2	1—2
25 ...	0·308	0·284	+0·024	0·314	0·294	+0·020	0·336	0·298	+0·038
30 ...	0·297	0·284	+0·013	0·302	0·288	+0·014	0·317	0·295	+0·022
35 ...	0·282	0·283	−0·001	0·287	0·282	+0·005	0·297	0·291	+0·006
40 ...	0·267	0·282	−0·015	9·272	0·276	−0·004	0·267	0·280	−0·013

1. Total effective insolation.
2. Total effective outgoing radiation.

1—2. gives the amount of net heating or cooling shown by plus and minus respectively.

It may be seen from the above table that on the average between latitudes 34.5° to 37.5° from the equator and in still higher latitudes the net cooling becomes larger than the net heating. The results obtained by different authorities vary only slightly depending upon different assumptions concerning the mean temperature of the earth, albedo, radiative characteristics of both long and short-wave radiations and the distribution of water-vapour and cloudiness in the atmosphere.*

* Simpson assumed that stratosphere contained about 0·03g/cm² of water vapour and 0·06g/cm² of carbon-dioxide. On this assumption he found that his first category of long wave radiation (5·5 to 7μ and more than 14μ) will originate in the stratosphere, his second category (8·5μ to 11μ and below 4μ) will originate either at the ground surface or at a cloud and his third category (7 to 8·5μ and 11 to 14μ) will be intermediate in amount between the black body radiation from the stratosphere and from the earths surface or a cloud. In this way he calculated the total outgoing flux by assuming a figure of 261 K for the latitudinal variation of earth's mean temperature with a mean cloud amount of 5/10 for all latitudes and gave a mean value of 0·271 cal/cm²/min. It is interesting to mention that if we accept Angstrom's formula (A=0·17+0·53c) for the albedo of the earth and take Simpson's figure of 5/10 for cloudiness we get the albedo figure of 0·43 and when multiplied by the solar constant 1·94g/cal/cm²/min we get a figure of 0·276, a value which compares favourably well with 0·271, the figure of the total outgoing flux given by Simpson.

As remarked by Charney,[4] Simpson overestimated the absorptive power of 0·03g/cm² of water vapour. The modern researches have proved that the stratosphere does not even contain 0·03g/cm². Despite this his approach was substantially correct as shown by later investigations.

As may be seen from the table, Albrecht's values are not very different from those given by Simpson. There is however a noteworthy discrepancy in the figures of long-wave radiation regarding

Table 1 represents only the mean annual conditions. The values of both incoming and outgoing radiation show an appreciable variation from month to month. Consequently the values of net monthly radiation differ considerably from the mean values. It is however this seasonal variation of the net radiation which is of greater importance in the control of temperature conditions than the mean net radiation. In the case of former it is assumed that a net gain or loss of heat has to be compensated by heat transfer from regions of heat excess to those of heat deficit in order to maintain the radiation balance on the earth. But this is not true for any month separately. An appreciable part of the surplus energy is used to increase the temperature. Similarly in case of negative net radiation, a considerable portion of the heat deficit is used to lower the temperature[5].

In July the net heating in West Pakistan amounts to an average figure of +1.00 cal/cm²/min as given by Simpson's values. The south-western parts of the country comprising the dirtricts of Chagai and Kharan have a gain of even more than 1.125 cal/cm²/min, thus forming part of the extensive hyperthermancial zone covering N. Africa and S. W. Asia.

Unlike July, the isopleths of net radiation in January show a latitudinal control in the country. The isolines of net cooling (negative net radiation) run in close sympathy with the latitudes so that the latitude of 30° may be taken to represent a net radiation loss of—0.050 cal/cm²/min and 40° of—0.100 cal/cm²/min. Consequently the January sea-level isotherms run almost parallel to the latitudes.

TEMPERATURE AS A FUNCTION OF THE ALTITUDE

The effect of altitude on temperature is about a thousand times that of latitude[6]. The variation of temperature per unit height is known as lapse-rate. The observations show that the temperature usually decreases with elevation from the surface to the height of the tropopause. Sometimes inversions are set up in the lower layers of the atmosphere due to the radiative loss of heat at the surface and the lapse-rate becomes negative. The inversions may also be set up in the upper air but are rare.

For the whole earth, the annual mean lapse-rate is approximately 0.27° F per 100 ft. This value holds good up to elevations of about 12000′. In regions with a

the tropics. Simpson finds the zone of maximum cooling at 25°N while Albrecht places it at the equator.

The figures of Phillips and Baur, however show some disagreement with those given by Simpson. This is mainly due to different assumptions regarding the atmospheric absorption, scattering and cloudiness. Instead of taking a uniform figure for the temperature of cloud-tops as done by Simpson, they assume that this temperature is mainly a function of latitude and should therefore vary from latitude to latitude. Assuming the distribution of temperature and pressure as given, they calculated the flux by dividing the water vapour spectrum into 3 categories, all with a coefficient of absorption of constant value and calculated the outgoing flux by utilizing the well-known formula for radiative transfer.

pronounced winter, the mean lapse-rate of that season is only 0.22° F per 100′ and even less in the lowest 1000′. In summers those regions have a mean lapse-rate of 0.36°F per 100′[7].

It has been shown by Hann[8] that latitude has no pronounced effect on the lapse-rate of temperature, and the effects of topography, exposure, state of the sky and incidence of the moist season are more important factors in determining the lapse-rate of temperature. The mean lapse-rate in West Pakistan, as calculated by the present writer is given by the equation

$t_h = 78{\cdot}5 - 0{\cdot}95_h$ (if height (h) is in meters) or

$t_h = 78{\cdot}5 - 0{\cdot}29_h$ (if h is in feet)

It may be mentioned here that the mean lapse-rate figure given above is not very different from the one given by Hill[9]. He gives a lapse-rate figure of 0·92°F for every 100 meters in the N.-W. Himalayas and Tibet.

The seasonal variation of lapse-rate depends mainly upon the changes from rainy to dry seasons and *vice versa*. The lapse-rate for January gives the equation.

$t_h = 65{\cdot}7 - 1{\cdot}35_h$ (h in meters)

The corresponding equation for July is

$t_h = 85{\cdot}6 - 0{\cdot}75_h$ (h in meters)

The slower rate of lapse-rate in July is mainly due to non-homogeneous air and the latent heat of vaporization which is released at the time of condensation of *m*T*u* air at upper levels. It is also partly explained by greater amount of cloudiness in July than in January.

The differences of lapse-rate between the windward and the leeward sides of the Himalayas are much greater than the seasonal variations. The lapse-rate is obviously much more rapid on the leeward side than on the rainy side. This is illustrated by the following equations of lapse-rate determined from stations situated in the same climatic environments. Voeikaf warns against lapse-rates determined from comparison of temperature at stations in different local environments[10] The following equations have been derived from the comparison of temperature at Rawalpindi (680m) and Murree 2320m) on the windward side and Gilgit (1330m) and Dras (3970m) on the leeward side. The mean lapse-rate on the windward side is given by the equation

$t_h = 72{\cdot}4 - 1{\cdot}07_h$ (h in meters)

and on the leeward side by

$t_h = 62{\cdot}1 - 1{\cdot}20_h$ (h in meters)

Here it is interesting to compare the equations of January and July on the two sides, of the mountain. The lapse-rate equation in January for the windward side is

$t_h = 50{\cdot}0 - 0{\cdot}75_h$ (h in meters) and for the leeward side it is

$t_h = 42{\cdot}0 - 1{\cdot}50_h$ (h in meters)

The corresponding equation in July for the leeward side is

$$t_h = 83{\cdot}6 - 1{\cdot}03_h \text{ (} h \text{ in meters)}$$

And for the windward side is

$$t_h = 87{\cdot}4 - 1{\cdot}25_h$$

The anomalous nature of July equation for the leeward side is most probably due to intense convective instability in the afternoon in this region which mixes the hot surface air with the cooler air aloft and thus prevents very high temperatures being produced on the surface.

The surface-temperature is in many ways influenced by the upper-air conditions. The changes thereof have direct repercussions on the temperature field beneath. It is therefore suggested to include here a brief discussion on the temperature conditions in the upper air over West Pakistan.

Fig. 1 shows the actual temperature distribution and isentropic surfaces in January and July over West Pakistan in the form of a vertical cross-section of upper air up to 5 km between Karachi and Peshawar through Quetta. The data utilized here have been taken from the Mem. Ind. Met. Dept. Vol. XXIX. part 2 for Peshawar and Quetta and from the Ind. Met. Dept. Sc. Notes Vol. VII No. 78 for Karachi. Table 2 gives the differences of the monthly normal temperatures at standard levels over Karachi, Quetta and Peshawar. In Table 2-A showing the comparison of Quetta and Peshawar, it can be easily seen that level for level Quetta is hotter than Peshawar, between 2 and 4 km. in practically all months of the year, the maximum difference of temperature being about 4°C. If $\triangle T$ denotes the difference of temperature between Quetta and Peshawar at height h, then $\frac{\partial(\triangle T)}{\partial h}$ is positive in the winter months and negative in the monsoon months up to the maximum height reached by the aeroplane ascents. This is chiefly due to a greater frequency of lapserates over Peshawar than over Quetta, in winter months and *vice versa* in the monsoon months[11] Table 2-B shows the comparison of temperature over Karachi and Peshawar. It is seen from this table that temperatures over Karachi are generally higher than over Peshawar except between 0·5 to 1 km during June to September when they are lower. This is due to the existence of a layer of cool moist air with high lapse rate below the inversions (associated with stratus) in these months. The largest differences between Karachi and Peshawar temperatures occur in January. Similarly it may be seen from Table 2-C that Karachi temperatures are higher than Quetta temperatures except at and above 2km above sea level during June to September when they are slightly lower. This has been shown due to the frequent incursion of old monsoon air with the westward movement of Bay of Bengal depressions. Largest differences between Karachi and Quetta temperatures occur in January[12].

TABLE 2-A

Monthly normal temperature differences between Quetta and Peshawar (Q – P) in °C

Height	January	February	March	April	May	June	July	August	September	October	November	December
4.0 kms	3.4	4.2	2.0	2.1	−0.3	0.8	2.0	1.7	−0.8	0.7	2.3	3.3
3.0 kms	2.0	2.3	1.6	1.8	0.6	2.1	3.2	2.9	0.9	0.8	0.7	2.6
2.5 kms	1.2	1.7	1.4	2.3	1.2	2.3	3.5	3.5	1.3	0.6	0.2	1.9
2.0 kms	0.0	1.4	1.3	2.2	1.4	2.5	3.7	3.5	1.3	−0.1	−0.4	−0.9
Surface	−6.1	−5.0	−5.1	−5.2	−6.0	−5.5	−4.3	−3.9	−6.3	−7.6	−6.3	−4.8

TABLE 2-B

Mean Monthly differences in temperature between Karachi and Peshawar (K – P) in °C

Height	January	February	March	April	May	June	July	August	September	October	November	December
3.0 kms	9.8	8.3	4.9	2.2	1.3	1.7	1.7	1.1	0.9	0	3.3	6.3
2.5 kms	8.8	7.1	4.4	2.3	1.5	1.7	1.4	1.6	1.2	0	1.9	5.4
2.0 kms	8.2	6.7	4.2	2.5	2.1	1.3	1.2	1.3	2.5	−0.3	1.3	4.8
1.5 kms	7.3	6.1	4.6	2.5	1.9	0.1	−0.9	0.7	1.2	0.2	1.7	4.6
1.0 kms	7.1	6.4	5.4	1.9	1.1	−3.5	−3.7	−2.6	−1.4	1.0	2.6	4.8
0.5 kms	8.3	8.3	7.2	3.0	−0.9	−3.8	−3.2	−3.2	−2.1	3.1	7.0	6.3
Surface	11.5	12.0	9.7	5.3	2.6	0.1	0.6	0.6	2.0	6.6	11.6	9.7

TABLE 2-C

Mean Monthly differences in temperature between Karachi and Quetta (K – Q) in °C

Height	January	February	March	April	May	June	July	August	September	October	November	December
3.0 kms	6.9	4.1	2.2	1.4	0.8	−0.8	−9.5	−0.8	−0.3	0.7	3.7	5.7
2.5 kms	6.9	3.2	2.1	1.2	0.8	−0.9	−1.8	−1.6	−0.6	0.6	2.2	4.4
2.0 kms	7.9	3.1	2.0	0.9	0.6	−1.3	−2.1	−2.1	−0.1	0.6	2.2	4.4
Surface	16.1	14.6	13.1	11.6	7.8	3.6	3.5	3.3	7.1	14.4	16.2	15.6

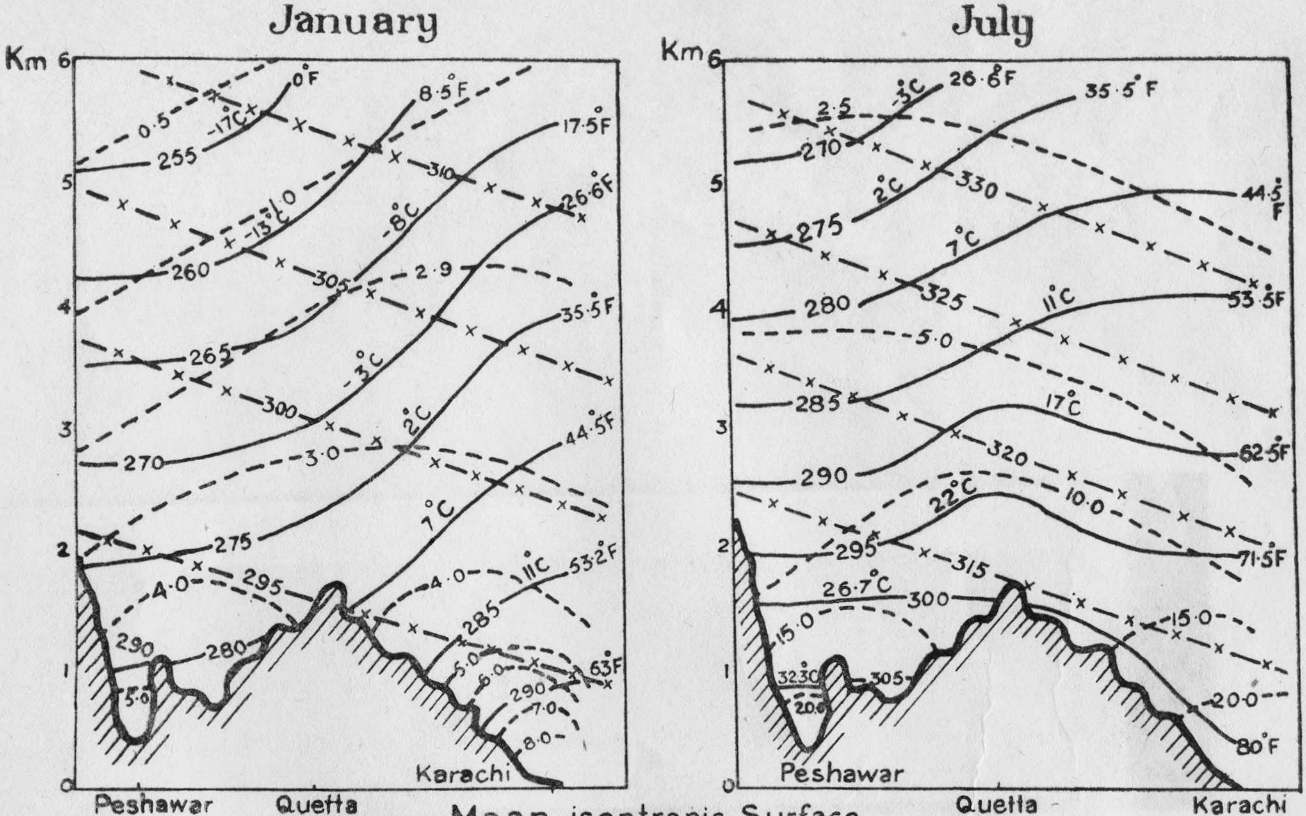
Narayan[13] has shown that at Peshawar, the general tendency in all months except March and April for the lapse-rate is to increase in value from the surface upward reaching a minimum between 1 to 1.5 km. Above this, the lapse-rate increases with height up to 3 km. Beyond this height he shows, it tends to decrease but that this tendency is absent in November, December and January. During the full force of monsoon the lapse-rates are small (August—5 to 6°C per km.). The lowering of lapse-rates near the surface is strongest during November and December The lapse-rates are highest in the early summer months.

Koteswaram, Raman and Parthasarathy, in a recent article[14] maintain that in winter the mean lapse-rate over Peshawar falls to 2°C per km. slightly above 12 km. and reaches the isothermal state near 17 km. On this basis they place the polar tropopause at a height of 12.5 km. over Peshawar and the mean tropical tropopause at 17 km on the parallel of 27°N. The thermal structure of the upper air over Peshawar mentioned above has been explained by Koteswaram etc. due to the statistical advection of the polar and tropical tropopauses over this station.

Narayan (*op. cit.*) shows that at Quetta the lapse-rates are comparatively small at all heights but in the early summer months the rate nearly equals the dry adiabatic value. In the monsoon months it becomes superadiabatic up to 2 km. above sea-level. In the months July and August there is observed a slight fall in the lapse-rates of temp. above 3.5 km.

Hariharan[15], discussing the temperature inversions over Karachi, remarks that they are very frequent within the first two km. According to him the mean height of the base of inversions varies from 0.3 km. in March to 1.1 km. in July, gradually decreases to 0.4 km. in October, attains maximum height of 1.3 km. in winter and then decreases again. According to him the mean thickness of the inversions has a stationary value for each season, 0.3 km. during winter, 0.4 during the early summer and 0.5 km. in the monsoon season and that the inversions are most frequent in months from April to September. The anomaly is explained by the life-history of the air reaching Karachi in these months. The air has travelled a long distance over the sea after leaving Iraq and has thus undergone two stages before reaching Karachi, namely the dry adiabatic condition over Iraq and the changes the air undergoes during its passage over the sea, *i.e.*, surface inversions and surface cooling due to the evaporation from the water-surface. The turbulence lifts these changes up with the likelihood of clouds. At the same time the lapse-rate below the base of the inversion layer tends to follow the dry adiabatic with humidity increasing to saturation up to the level and then suddenly decreasing to its initial value (which it had over Iraq) above the inversion layer. Hariharan also remarks that the inversions over Karachi are in general associated with clouds mostly of stratus and cumulus type. In the winter months the air is dry and both clouds and inversions are rare.

Now, we turn to the isentropic conditions. An isentropic surface makes



Mean isentropic Surface
between
Karachi & Peshawar through Quetta

——— *Mean observed temperature in K, °C & °F.*
x—x—x *Mean potential temperature in K*
- - - - *Vapor pressure in mm of Hg.*

use of the potential temperature* which is defined as the temperature, that a given parcel of air would attain, if it were compressed, without gain or loss of heat to a standard pressure (in this case 1000 mb).

Fig. 1 shows such isentropic surfaces for the air of West Pakistan for January and July separately. It clearly shows that the potential temperature everywhere increases with height, the rate of increase being higher in July than in January. The average rate of increase of January and July is nearly 5K per kilometer. Since it follows from the definition of potential temperature that given a constant pressure it increases with the actual temperature, the former normally increases southward.[17] This is amply illustrated by this diagram, in which the isentropic surfaces slant downward from Peshawar to Karachi. It may be seen that on the average, level for level Peshawar is cooler than Karachi by about 5 to 7K. The vertical displacement of the isentropic surfaces, in January and July amounts to about 10K below and above the mean surface respectively. In the same figure, the isopleths of vapour pressure have also been drawn to emphasize the role of water-vapour in the distribution of potential temperature. The rapid increase of potential temperature with height in July is also explained by greater amount of water vapour and the resultant release of latent heat at the time of condensation than in January when the air has a poor amount of water vapour and hence there is a poor amount of latent heat.

TEMPERATURE AS A FUNCTION OF THE PREVAILING AIR MASSES AND WINDS

Radiative balance and altitude are static factors in the control of air temperature and are most powerful during calms. But, when atmosphere is active, the imported temperature often gains over the local temperature and at times the synoptic control completely masks the solar and altitudinal effects. Hence, while investigating the thermal characteristics of a climate, a full knowledge of the free air is required and especially of its inherent properties and flow-patterns at different levels. Slight changes in the patterns of upper-air circulation can bring wide variations of temperature on the surface.

The free atmosphere over West Pakistan poses some of the most difficult problems of physical and dynamical meteorology. This complexity is the result of manifold contrasts, which exist in the various air masses prevailing in various parts of the country and more often than not supply causes for frontogenesis and frontolysis in and around the country. The differential heating and cooling of the land mass

*The potential temperature is given by the formula[16]

$$\log \theta - \log T = \frac{\gamma - 1}{\gamma} (\log p_0 - \log p) = 0.288 (\log p_0 - \log p)$$

where p_0 the standard pressure

T , the initial temperature

p , the initial pressure

θ , the potential temperature.

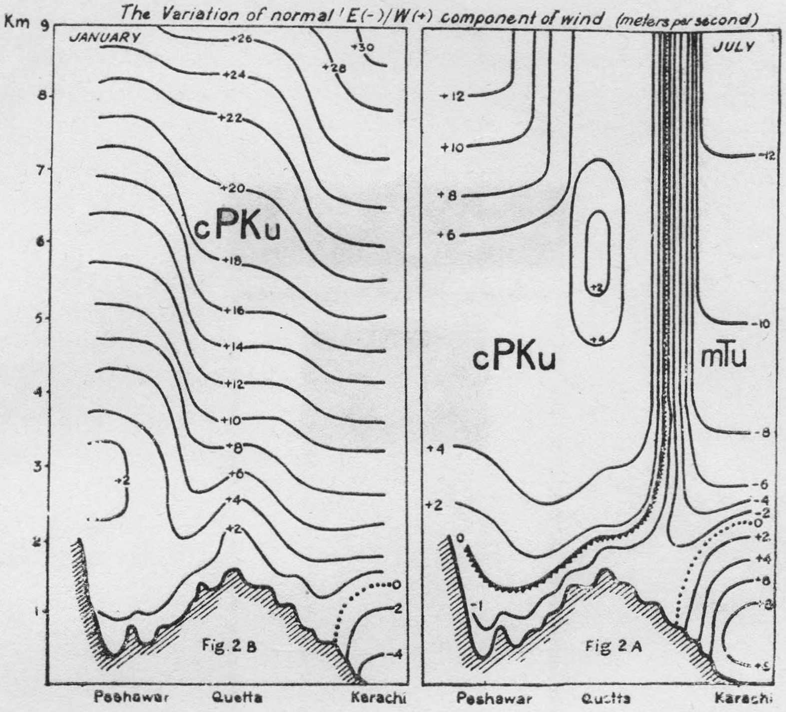
of the sub-continent and the waters of the Indian Ocean in various seasons account for the delivery and eventual replacement of gigantic air masses with different thermal and moisture properties so as to make the country an active arena of conflicting air-currents all the year round.

The principal air masses involved in the weather of West Pakistan are *m*T*u* and *c*PK*u**. The source of monsoon air (*m*T*u* or E*m*) lies in the tropical regions of the Indian Ocean. In May, when the South Asian pressure system show tendencies of weakness and the sub-continental trough has been steepened maximally by June, the *m*T*u* air is delivered from the tropical regions northward to make up for this polar trough. Considerable doubt has been expressed by various authorities on the role of air from southern hemispheric tropics in the monsoon air reaching the sub-continent. The researches of Deppermann.[28] Thomson (*op. cit.*) Wood and Riehl have shown that although much of the *m*T*u* is originated on that side of the equator, the components from the northern hemisphere form a substantial part of this air. Moreover before reaching West Pakistan the air has travelled at least 1200 miles in the northern hemisphere and therefore hardly justifies itself to be labelled as of southern hemisphere origin.

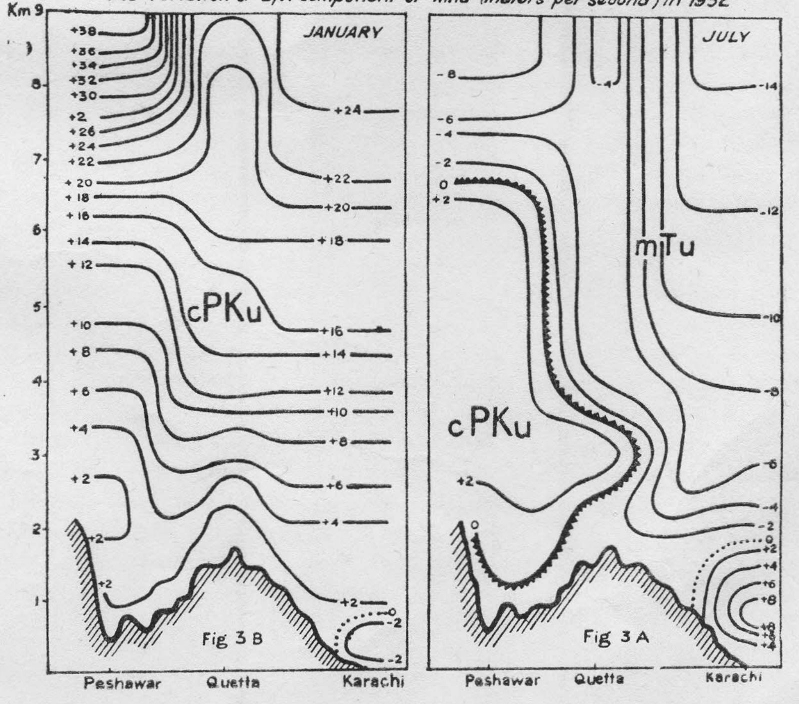
The *m*T*u* reaches the sub-continent in the form of unmodified equatorial air. The bulk of the air flow is zonal and westerly except in the northern plains where it becomes easterly.[29] The two components produce a vague convergence at their junction in the Gangetic plains. Fig. 2 shows variation of normal E/W component of wind in West Pakistan in the form of cross-section between Karachi and Peshawar through Quetta. It may be seen from Fig. 2A that most of the components of *m*T*u* are easterly. The westerly components are both narrow and shallow

*The author is reluctant to place here the *c*TK*u* which is a misnomer. Petterson,[18] Trewartha[19] Miller,[20] Haurwitz and Austin (*op. cit.*), all show *c*TK*u* air in the Chinese and Russian Turkistan in summer. The view is mainly due to the exponents of ITF in the sub-continent like Roy[21] Banerjee[22] Ramanathan[23, 24, 25], Malurkar and Sawyer.[26] They explained the structure of monsoon depressions by involving two or three air masses—*m*T*u* or E*m* on the south, *c*TK*u*, on the north and west and Transitional Far Eastern Air (Malurkar) or Old monsoon air (Roy) to the east and north-east of the ITF. This explanation was no doubt more elaborate and scientific than the pre-1930 school of Blanford, Walker, Simpson, Hemraj and Normand which did not make use of the air mass analysis. But the exponents of ITF failed to realize that the so-called *c*TK*u* was actually of high latitude origin and if it was not as cold as *c*PK*u*, it was mainly due to its passage over a supraheated Turkestan. Thompson[27] rightly argues that in case of N.-W. India this air could not be possibly cold after having undergone fohn descent from the plateau of Afghanistan and Iran. Thompson rejects the idea of ITF and calls it an unfortunate myth. He says, "The use of climatological records of surface winds on which to base the traditional theory of ITF was a very bad mistake indeed. Tropical winds are notoriously fickle and light and there is much danger in using light surface winds in meteorological analysis. It is fantastic that the theory of the ITF, built on such a foundation can have so persisted". The present writer is inclined to feel that the time is overdue to change the name of ITF into SAPF (South Asian Polar Front). This would naturally be an extension south-west-ward of the WPPF

The Variation of normal E(-)/W(+) component of wind (meters per second)



The Variation of E/W component of wind (meters per second) in 1932



so that they become absent to the north of Sukkur and above a maximum height of 2 km. respectively. In the north-east of the country the *cPKu* (*c*TK*u* ?) air persists at 1 to 2 km. above the surface and level for level it is weaker than the *m*T*u* air.

About the close of August the *m*T*u* air shows signs of retreat so that by the end of September the country has been cleared off this air and replaced by the cPKu. Increasing amounts of the *c*PK*u* air pour into the country during October and November.

In December and January this air has gained maximum strength. This is nearly double of its velocity in summer. It blows with westerly to northwesterly components except over the southern part of the lower Indus valley where at lower levels it assumes an easterly component between azimuths 0 to 30 due to the deflection caused by the outlying spurs of Kirthars, an important factor in the kinematics of the surface air in this region (see Fig. 2B) The north-westerly components in the northern parts of the country, are again due to the deflection of general westerly currents affected by the Hindukush.

The winds belong to the zonal westerly over Asia*. Ramanathan and Ramakrishnan, however, maintain that the movement is mainly meridinal.[30] As the westerlies move southeastward into India, they give place to increasing depths of easterlies or the so-called N-E monsoon. The slope of the surface of separation of E/W component increases southestward into India, its average value between latitudes 20 & 24°N (at long. 80°E) being 1 in 400 and between 12° and 16°N being 1 in 100.[31] However, it may be seen that no part of the country is affected by the N-E monsoon. The present writer, therefore, does not agree with Petterson's (*op. cit*) use of the word "N-E monsoon" for the air over Karachi in winter. As shown previously the easterly components over Karachi in winter are limited to only 2 km above the surface and that they are induced by topographical inequalities in this region. And even if we accept for a moment that these components belong to the N-E monsoon, then what about the zonal westerlies involving bulk of the air over Karachi above 2 km in this season.

TABLE 3

Deviation of mean temperature (°F) in 1932

Month	Peshawar			Quetta		
	Normal	1932	deviation	Normal	1932	deviation
January ..	51.7	59.0	+7.3	38.9	46.0	+7.1
July ..	91.3	90.4	+0.9	79.5	81.4	+1.9

*** It is regretted that the important work of Naqvi on the Zonal currents of S. Asia could not be assessed before this article was completed.**

It has been previously stressed that the flow patterns of circulation exert the dynamic control on the field of temperature. Any fluctuation in these patterns is naturally followed by wide departures of temperature. In Fig. 3 the writer has shown the variation of E/W component of wind in January and July, 1932, a year of strong monsoon circulation. Table 3 shows the effect of strong monsoon circulation in raising the surface temperature of the country. The data of Karachi was not available and it had to be left out. The exaggerated effect in January is due to a weaker solar control in this month.

MEAN MONTHLY & ANNUAL TEMPERATURE

Mean annual temperature is the briefest expression of the temperature conditions of a place. Map No. 1 illustrates the average annual temperature of the country. Isopleths have been drawn both for the actual and sea-level temperature. The actual temperature, has been interpolated for the regions above 7000′ in altitude by the help of lapse-rate equation mentioned in the preceding account of temperature gradient. The effect of latitude and altitude can be clearly seen from the map in which the isotherms decrease in value from south to north and from lower to higher altitude.

The middle and lower Indus plains excluding the coastal areas, form the warmest part of the country (80°F). The upper Indus plain, the Hamun-i-Mashkhel depression and the coastal areas are other warmer parts of the country (75°F) where sometimes very high temperatures may be recorded in summer comparable to those in the middle and lower Indus plains. Due to the absence of high-altitude observatories in the country, no information is available about the temperature conditions in the Himalayas, Hindukush and Karakorams above 7000′ contour. Decidedly the highest crests of these ranges make the coldest parts of the country.

It may be mentioned here that the mean temperature in the country is nowhere normal to the latitude. The equation expressing the relation of the dependent variable, the temperature (T) with the independent variable, the latitude (ϕ) is given by Forbes[32] as:—

$$t = 17.8° + 44.9 \cos^2 (\phi\text{-}630°)°C$$

The standard figures for the latitudinal distribution of temperature most commonly used in the calculation of anomalies are those given by W. Meinardus and Hann-suring, converted into degrees F for the first time by Conrad and Pollak. The standard temperature figures for the latitudes of West Pakistan are reproduced below from Conrad and Pollak (*op. cit*) in Table No. 4, interpolated by the author.

TABLE No. 4

ϕ	Year	January	July	ϕ	Year	January	July
24	75.7	67.2	82.2	31	67.4	56.3	80.6
25	74.5	65.7	82.1	32	66.3	54.5	80.0
26	73.3	64.2	82.0	34	64.1	51.0	78.9
27	72.1	62.6	81.8	35	63.0	49.3	78.4
28	70.9	61.1	81.5	36	64.1	47.7	77.8
29	69.7	59.6	81.3	37	65.2	46.1	77.1
30	68.5	58.1	81.1				

The isanomalous lines have been drawn on the basis of difference between the observed sea-level temperatures and those normal for the latitude given in Table No. 4. It may be seen that the mean temperature has a positive anomaly of 5° near the coast and 10° in the northern half of the country. The anomalies are due to excessive net heating in summer, which was mentioned in the preceding discussion of heat balance. It is interesting to note that in January the temperature is normal to the latitude, perhaps mainly due to a stronger zonal circulation in winter while the anomalies of the mean annual temperature are almost wholly contributed by summer, for the reason previously discussed.

The Maps 2 and 3 show the temperature conditions in the extreme months—January and June, respectively. The temperature distribution can be better understood from the maps than from many words of description.

The march of insolation provides the dynamic basis of the annual cycle and normally a general lag is observed between temperature and solar radiation amounting to 25 days for air temperature and 55 days for sea-temperature.[33] But sometimes the irregularities exist and disturb the normal progression of temperature to be expected from the solar-radiation curve. In West Pakistan, the monsoon rains which begin in the month of July cool the air so that the temperature curve exhibits two maxima; one just before and the other just after the rains, the former maximum being naturally higher than the latter. Such are the conditions in the lowlands and the sub-Himalayan parts of the country. In the highlands, which are least affected by monsoon rains, the temperature curve is quite symmetric and an appreciable lag is observed between temperature and solar radiation. The lag is highest in the quadrangle of the Baluchistan plateau and the Hindukush-Karakoram ranges. For instance, Quetta shows a lag of 25 to 30 days in case of highest and 40 to 45 days in case of lowest temperature. Skardu has a still higher lag amounting to about 50 days and 40 days for the highest and the lowest temperatures respectively. The north-western highlands and the intermont depressions have a lag of 5 to 15 days for the highest temperature and about 30 days for the lowest temperature.

TABLE 5
Absolute Maximum Temperature (°F)

Station		January	February	March	April	May	June	July	August	September	October	November	December	Year
Sialkot	...	81.0	86.6	104.5	111.0	118.6	120.0	119.5	121.3	107.7	103.7	94.6	82.0	121.3
Rawalpindi	...	79.9	83.9	99.0	106.0	114.0	118.0	117.0	110.0	107.0	99.0	88.0	82 0	118.0
Murree	...	65.0	71.4	83.0	90.0	95,0	102.0	99.0	92.8	82.9	83.7	74.2	69.6	102.0
Lahore	...	82.0	90.4	106.3	111.8	120.3	119.5	118.0	113.6	108.6	106.5	92.3	86.6	120.3
Cherat	...	67.3	72.8	82.4	93.4	103.0	111.0	106.5	100.9	96.9	88.9	79.9	70.8	110.0
Peshawar	...	76.6	81.6	98.5	107.5	115.0	119.0	118.0	112.7	106.0	102.2	88.6	81.0	119.0
Khushab	...	81.2	86.3	102.3	116.1	119.1	120.4	119 1	111.4	108.4	105.3	94.3	85.2	120.4
Dera Ismail Khan	...	82.7	88.7	106.5	113.5	119.5	121.5	120.5	113.5	110.5	105.5	92.3	84·8	121.5
Montgomery	...	83.0	92.5	106.2	113.9	121.9	120.6	120.4	112.9	110.4	107.4	96.3	86.0	121.9
Multan	...	83.3	90.6	108.2	114.0	120.5	121.0	119.5	112.4	111.4	106.4	103.9	93.9	121.0
Karachi	...	89.4	93.5	105.3	111.4	117.6	114.2	109.6	99.1	103.4	107.9	99.9	90.4	117.6
Hyderabad	...	95.1	99.4	112.2	118.1	121.0	122.2	113.1	110.2	108.7	117.2	100.7	92.1	122.2
Jacobabad	...	88.5	100.7	111.8	117.1	123.0	126.0	126.0	116.6	115.3	108.9	99.5	89.5	126.0
Quetta	...	77.7	79.8	84.2	90.0	97.5	102.3	101.0	99.0	97.1	89.1	79.7	73,3	102.9
Chaman	...	80.3	78.1	85.3	94.5	105.0	112.0	109.2	107.0	104.2	94.2	85.3	79.8	112.0
Jask	...	82.2	88.3	92.3	102.2	110.2	105.2	105.2	106.7	103.7	102.2	91.3	84.3	110.2
Kalat	...	80.5	74.5	82.7	95.7	97.9	102.8	103.0	100.5	97.3	87.3	83.9	82.3	103.0
Kabul	...	75.2	77.2	84.1	86.1	102.2	100.1	112.1	103.1	100.1	97.1	91.0	82.2	112.1
Gilgit	...	55.8	64.4	81.9	93.2	105.9	110.5	113.2	108.0	104.3	92.5	77.5	59.6	113.2

TABLE 6

Absolute Minimum Temperature

Station		January	February	March	April	May	June	July	August	September	October	November	December	Year
Sialkot	...	31.6	31.0	40.1	49.0	57.1	66.3	67.8	66.2	60.2	49.2	32.1	29.3	29.3
Rawalpindi	...	24.9	28.7	37.9	42.0	51.0	62.2	60.1	63.1	67.0	42.0	25.9	23.9	23.9
Murree	...	18.0	16.7	20.0	28.5	32.0	42.0	49.4	46.4	42.9	37.7	23.9	22.4	16.7
Lahore	...	29.2	30.5	40.2	47.8	60.7	64.5	68.9	68.2	62.6	46.3	32.5	29.8	29.2
Cherat	...	27.0	25.6	25.5	40.0	45.1	58.0	58.2	60.2	51.6	41.6	38.0	27.6	25.5
Peshawar	...	28.8	29.2	37.9	42.2	51.3	63.0	65.8	66.0	58.0	44.9	24.7	25.7	24.7
Khushab	...	25.0	31.4	40.1	50.8	58.5	60.0	69.8	69.9	67.7	47.8	31.1	30.5	25.0
Dera Ismail Khan	...	26.0	28.0	38.9	43.8	58.7	59.7	65.8	68.8	57.7	45.8	20.0	26.0	26.0
Montgomery	...	30.5	32.3	39.5	53.0	59.5	68.0	69.5	67.5	63.0	50.5	38.3	31.5	30.5
Multan	...	40.1	43.1	47.4	59.5	66.6	71.2	72.8	73.5	68.7	57.0	47.9	41.0	40.1
Hyderabad	...	36.0	37.9	40.5	56.7	58.7	68.0	73.0	70.8	66.0	55.4	44.1	38.8	36.0
Jacobabad	...	30.3	29.0	39.6	51.3	62.3	69.6	72.9	72.9	60.5	57.2	32.7	21.6	29.0
Quetta	...	3.3	11.8	15.8	29.4	33.6	42.9	46.9	44.9	33.8	23.9	14.8	10.8	3.3
Chaman	...	15.1	13.1	13.1	40.1	46.1	52.1	61.6	56.1	48.1	32.1	27.1	21.1	13.1
Kalat	...	—6.4	1.4	10.0	17.0	26.8	33.4	41.0	31.8	19.9	17.2	5.8	4.4	—6.4
Kabul	...	—0.2	0.4	19.8	29.6	41.4	45.4	49.8	49.4	36.4	28.4	18.4	5.6	—0.2
Gilgit	...	22.1	22.1	34.3	36.1	45.9	40.9	56.7	58.3	50.5	41.3	32.1	21.9	21.9

The "record" highest and lowest temperatures are of great interest to the climatologists since they supply additional material on the temperature characteristics of a region. Moreover, the absolute temperatures can serve as a criterion of thermal or radiation continentality. Whereas the lowest temperatures on the earth have been recorded in the centre of landmasses in high latitudes, the extreme highest temperatures have occurred in the trade-wind deserts in the low latitudes. The occurrence of absolute lowest temperatures in the regions mentioned above is mainly for two reasons. Firstly, inside the polar circles on at least one day of the year the sun does not rise and the loss of heat continues throughout the 24 hrs., and secondly these regions are always dominated by cold and stable polar air-masses which become stagnant and tend to be colder and colder, thus producing extraordinarily low temperatures in these regions[34]. Oimekon, Siberia has recorded the lowest absolute temperature on the earth (−108°F).

The absolute highest temperatures in the trade-wind deserts are due mainly to a longer duration of the sun-baking period, in these regions. The highest temperatures on the earth are found near the tropic of cancer and not near the equator is due to the fact that in the former regions the vertical rays of the sun strike dowh somewhere for 85 days (May 10 to August 3) between 17°35′N and 23°30′ N while the regions between the equator and lat. 5°52′ N receive the vertical noonday rays only during 15 days, March 21-April 5 and 15 days again, September 8-23, and never have those rays at more than 29° 19′ from the vertical[35]. Backinsale[36] has shown that even at 27°30′N, the altitude of the zenithal sun does not drop below 80° for 12 consecutive weeks. He further remarks that the greater intensity of sun-baking period near the tropics is also due to a longer duration of daylight in summer and greater transparency of the atmosphere than in the equatorial regions. As a result, the hottest areas of the world surface occur on land-masses between latitudes 16° and 36°. The highest temperature observed on the earth is 136.4°F and was recorded at Al-Aziziya (32°N) in the Libyan desert.

Tables 5 and 6 give the absolute maximum and minimum temperature respectively, recorded at some important stations in the country up to 1903. It is interesting to find that the absolute maximum temperatures are quite uniform over the country as a whole. The range of variation between the highest absolute maximum and lowest absolute maximum is only 23.2°F. The records show that nowhere in the country the absolute highest maximum temp. is below 100°F. Even Murree has recorded 102.8°F, which is the lowest absolute maximum observed in the country. The highest absolute maximum temperature has been recorded twice at Jacobabad (126°F). It is 10.4°F less than the first world highest record at Al-Aziziya, 8°F less than the second highest record at Greenland

Ranch. Death Valley[37] and only 2°F less than the third highest record at Wadi-Halfa. Thus it may be seen that the country around Sibi and Jacobabad is among the hottest spots on the earth.

The absolute minimum temperatures, on the other hand show less uniformity in the country. The range of variation between the highest absolute minimum and lowest absolute minimum is 46.5°F. The former has been observed at Karachi (40.1°F) while the latter has been recorded at Kalat (−6.4°F) which lies on the path of cold-waves entering West Pakistan from Iran and Afghanistan.

MEAN ANNUAL AND ABSOLUTE RANGES OF TEMPERATURE

The mean annual range of temperature is expressed as the difference between the temperatures of the warmest and coldest months. Undoubtedly this is the most convenient way for summarizing the seasonal contrasts in the temperature regime. Moreover, the annual range of temperature is a very useful measure of thermal continentality and oceanity. But since the annual range of temperature (A) is in part also a function of latitude (ϕ), the values of A have to be reduced to equality by the sin of ϕ in order to give k, the coefficient of thermal continentality. Table 7 gives the values of A and k for some important stations in West Pakistan. The values of k have been calculated by Conrad's formula*.

TABLE 7

Station	A	*k*	Station	A	*k*
	OC	%		OC	%
Badin	16.5	33.0	Lyallpur	21.7	38.5
Bannu	22.3	40.2	Lasbela	17.1	34.5
Chaman	26.3	51.0	Montgomery	22.7	41.1
Cherat	22.0	39.0	Multan	22.7	50.3
Dalbandin	25.3	57.7	Murree	18.1	30.0
Drosh	25.9	49.4	Nokkundi	24.8	56.3
Fort Sandeman	23.4	42.8	Pangur	21.7	47.5
Gilgit	24.7	46.0	Parachinar	20.9	34.5
Gawadar	11.1	17.4	Peshawar	22.0	39.4
Hyderabad	16.7	33.3	Quetta	23.0	51.1
Jacobabad	22.8	50.6	Rawalpindi	22.8	41.3
Karachi (Manora Island)	10.5	15.7	Sialkot	21.5	38.2
Kalat	22.8	50.6	Sibi	24.4	55.1
Khushab	22.4	40.4	Sukkur	19.4	41.0
Lahore	21.4	38.0	Skardu	32.6	65.2

*Conrad's formula states thus:—

$$k = \frac{1.7A}{\sin(\phi + 10)} - 14$$

where

A=Annual range of temperature in degrees C

ϕ=the latitude.

The table clearly shows the physical correlation which exists between the mean annual range of temperature and the degree of continentality. The annual ranges of temperature are everywhere less than 25° F near the coast due to the obvious effect of tempering by the neighbouring sea. The degree of continentality is nowhere more than 20 per cent near the coast. The largest ranges of temperature (over 45°F) are found in the trans-Himalayan arid region and the Chagai-Kharan Desert, where the index of continentality is above 50 per cent. The isopleths of annual range of temperature in the country have been drawn on Map 4.

Table 8 shows the absolute ranges of temperature at selected stations in West Pakistan. The monthly absolute ranges in the lowlands and on the windward slopes of the Himalayas show two maxima, one in spring and the other in autumn, the former being higher than the latter. This is in response to the curve of mean monthly diurnal range in these areas. In the trans-Himalayan region the highest absolute range is found to exist in June since the highest monthly diurnal range also occurs in this month. In the Baluchistan plateau, although the curve maintains the autumn maximum, it shifts the spring maximum into the cold season. This characteristic is most probably inherited from the absolute maximum and minimum temperature curves, which show greatest range of variation in the cold season.

PERIODIC AND APERIODIC DIURNAL RANGES OF TEMPERATURE

The amount of the diurnal range of temperature, or the diurnal amplitude of temperature is a very important climatic element. This element is expressed by the difference between the mean temperatures of the warmest and the coldest hours of the day and is then called the "periodic amplitude" or it is expressed by the difference between the mean minimum and the mean maximum of the month and is known as the "non-periodic (aperiodic) amplitude (Hann—*op. cit.*). The surface temperature shows a clearly defined maximum at about two hrs. afternoon and a minimum shortly before sunrise. In the free atmosphere the daily range of temperature diminishes with increasing height and a lag in the time of maximum is also observed. The actual diurnal range observed within any selected interval of 24 hrs. will depend largely on the whether at that time. A clear sunny day followed by a clear clam night will yield a range of temperature for in excess of the average, while a cloudy day followed by a cloudy night may give no appreciable variation of temperature during the whole interval (Brunt—*op. cit.*). There is however no simple statement for the effect of latitude on the diurnal range of temperature. The effect is most probably very minor. Diurnal ranges of temperature, generally, increase with latitude up to the sub-tropical latitudes. In middle latitudes daily ranges vary less with latitudes than with distance from the sea and season. In very high latitudes diurnal ranges decrease again owing to lessened effectiveness of the daily succession of sunlight and darkness[38] There is again no definite relation between the diurnal range of temperature and continentality. Whereas the diurnal range of temperature is nowhere more than 40°F

TABLE 8

Absolute Range of Temperature (°F)

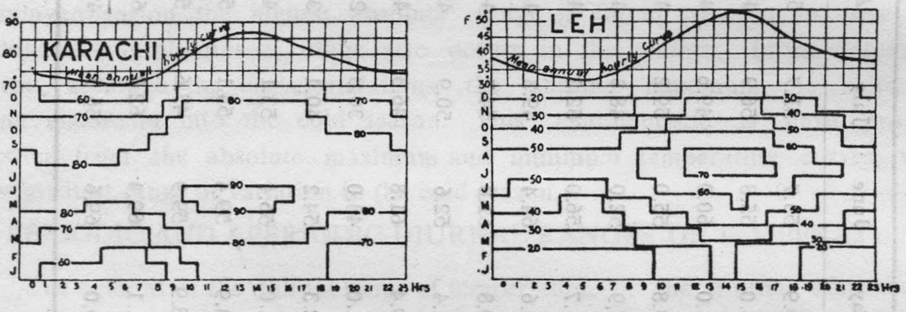
Station		Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Sialkot	...	49.4	55.6	64.4	62.0	60.9	53.7	51.7	55.1	47.5	54.5	62.3	52.7
Rawalpindi	...	55.0	55.2	61.1	64.0	63.0	55.8	56.9	46.9	50.0	57.8	62.1	58.1
Murree	...	47.0	54.7	63.0	61.5	63.0	60.0	49.6	46.4	40.1	46.0	50.3	47.2
Lahore	...	52.8	59.9	66.9	64.0	59.8	55.0	59.2	45.4	46.0	60.2	59.8	58.8
Cherat	...	40.3	47.2	56.9	53.4	57.9	52.0	48.3	40.7	45.3	43.3	41.9	43.2
Peshawar	...	47.8	52.4	60.6	65.3	63.7	56.0	52.2	46.7	48.0	56.1	63.9	55.4
Khushab	...	56.2	54.9	62.2	65.3	60.6	64.4	49.3	41.5	50.7	57.5	59.2	54.7
D. I. Khan	...	56.7	60.7	67.6	69.7	60.8	61.8	54.7	44.7	52.8	59.7	64.3	58.8
Montgomery	...	52.5	60.2	67.4	60.9	62.4	52.6	50.9	45.4	47.4	56.9	58.0	54.5
Multan	...	54.3	58.6	67.2	63.4	59.4	61.8	46.3	40.4	49.3	56.1	69.9	63.9
Karachi	...	49.3	50.4	58.9	51.9	51.0	43.0	36.8	25.6	34.7	50.9	52.0	49.4
Hyderabad	...	59.1	61.5	71.7	61.4	62.3	54.2	40.1	39.4	42.7	61.8	56.6	53.3
Jacobabad	...	58.2	71.7	72.2	65.8	61.0	56.4	53.1	43.7	44.8	61.7	66.8	57.9
Quetta	...	74.4	68.0	68.4	60.6	63.9	59.4	54.1	54.1	63.3	65.2	65.7	62.5
Chaman	...	65.2	65.0	72.2	54.4	58.9	59.9	47.6	50.9	56.1	62.1	58.2	58.7
Kalat	...	68.7	73.1	72.7	78.7	71.1	69.4	62.0	68.7	77.4	70.3	78.1	77.1
Gilgit	...	33.7	42.3	47.6	56.1	60.0	69.6	56.5	49.7	53.7	51.2	45.4	37.7

on the sea as shown by the observations from H. M. S. Challenger, it shows considerable variation on land from place to place. Although, in the map of Shaw[39] showing the variation of diurnal range of temperature on the globe, the central parts of the continents can be seen having values of above 30°F, the relation is by no means simple. On the same map Quetta can be seen with a much larger diurnal range than many of the stations in Central Asia. As it will be shown later by the writer, Kalat has a mean yearly diurnal range of 38.8°F while the corresponding figure for Gilgit is only 19.5°F although both the stations have nearly same coefficients of continentality.

Fig. 4 shows the thermoisopleths of mean yearly and seasonal march of diurnal temperature for Karachi and Leh respresenting the maritime aud continental conditions

Fig. 4

Thermoisopleths



respectively. The figure clearly shows that so far as the mean conditions are concerned, the time of maximum and minimum temperature shows no great variation at these stations. The actual time of maximum at Karachi is 1337 I.S.T. and of minimum 0529 I.S.T. The corresponding figures for Leh are 1355 and 0457 I.S.T. (Hill—*op.cit.*) Karachi records the maximum only 18 minutes earlier than Leh. The minimum is recorded about 32 minutes after it is recorded at Leh. This slight variation is due to the effect of land and sea breezes at Karachi. In both cases the curves of mean annual diurnal range or symmetrical, the increase from the minimum to maximum occupies a shorter time than the fall from maximum to minimum.

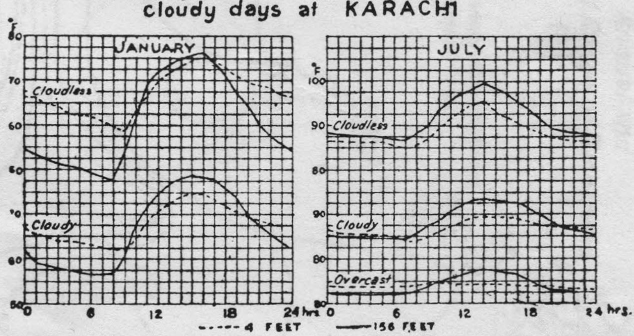
The periodic amplitude of the mean annual diurnal temperature at Karachi is 19.1°F and at Leh it is 25.2°F. The difference is explained by the different local climatic environments. Leh is situated in a continental mountain desert and Karachi in a coastal desert enjoying the moderating influence of the neighbouring sea. The difference in the diurnal ranges of Karachi and Leh would be much greater in case, the former station had more powerful breezes than now. For instance the difference of diurnal range between Leh and Calcutta is 18.7°F against 6.1°F observed between Leh and Karachi. The smallness of amplitude at Calcutta is, of course, not only due to strong breezes but also to other factors like greater amount of cloudiness and water vapour present in the air of Calcutta than at Karachi.

The periodic amplitude of the seasonal diurnal range at Karachi varies considerably from Leh. The mean diurnal range at Karachi is highest in autumn (Nov. 27.4°F) and lowest in the late summer (Sept. 10.0°F) since autumn is the driest and late summer the wettest season for Karachi. Leh, on the other hand, has the highest diurnal range in July (27.4°F) and lowest in March (21.9°F).

As mentioned previously, the range of the diurnal temperature variation at a place would depend largely on the amount of cloudiness and water vapour present in the air at that time. The clouds serve to reduce the diurnal range of temperature. They also reduce the inversions originating as a result of nocturnal radiation which are very common in winter. The net result is a relatively smaller amplitude in winter than it would otherwise be. It is mainly due to cloudless skies and consequent inversions that, in most parts of West Pakistan, high amplitudes of diurnal temperature are recorded in spring and autumn. Mal, Desai and Sircar,[40] in their study of the lapse-rate variation of temperature at Karachi have given useful data on the effect of cloudiness and inversions on the amplitude of diurnal temperature. Fig. 5 shows the diurnal temperature curves for Jan. and July for two different heights under different states of the sky. The figure is based on data given by them. The curves are very instructive and clearly show the effect of cloud in reducing the diurnal temperature at both heights. The rapid increase in temperature in the early morning and rapid decrease in the early evening on cloudless days is quite marked at both heights. Taking the curves for individual months, one can see that in January temperature changes during clear weather are more rapid than under average conditions and especially so at 4 ft. The diurnal range of temperature on cloudy days is reduced to about 2/3 of the value on cloudless days at 4′ and to about 3/4 of the corresponding value at 156′. The curves also show that on the average at 1500 (I. S. T) a cloudy day is warmer than a cloudless day by about 2.5°F at 4′ and by about 0.5°F at 156′ whereas the cloudy nights are warmer by about 9°F at 4′ and 3.8°F at 156′ at the time of minimum temperature. In the month of July, the overcast skies, on the whole, reduce the diurnal range to

Fig. 5

Mean hourly values of temperature on clear and cloudy days at KARACHI

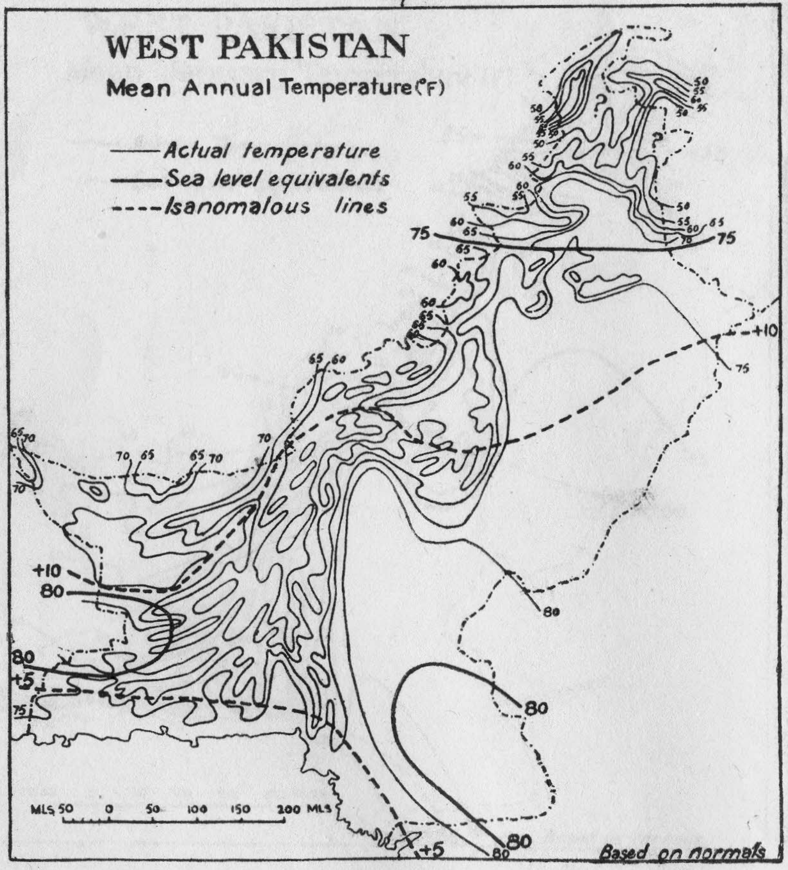


about 1/2 of the value on cloudless days at 4′ and to 1/5 at 156′, on cloudy days the reduction is 3/4 at 4′ and 1/2 at 156′ of the value on cloudless days. The cloudless days are warmer by about 7.0° at 4′ and 5.0°F at 156′ than cloudy days at the time of maximum and by 2.2°F at 4′ at the time of maximum temperature.

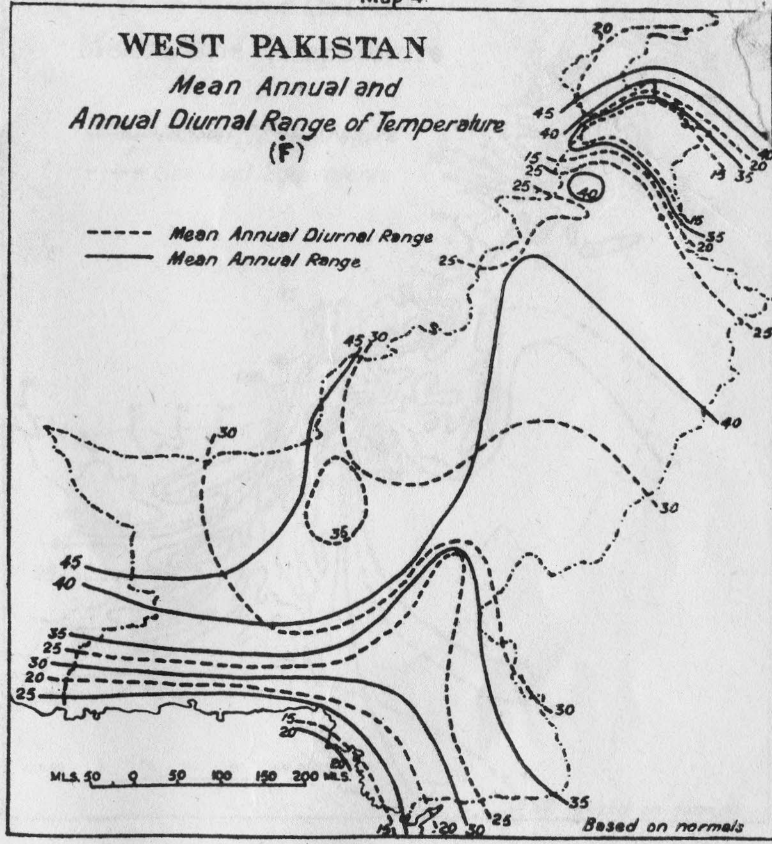
Since the heat is transmitted upward from the surface of the earth by turbulence and to a lesser extent by molecular conductivity, a general lag in the time of occurrence of maximum and minimum temperature is observed with increasing height. For instance, as shown by Mal, Desai etc. there is a lag of 46 minutes in the times of occurrence of maximum temperature at 4′ and 156′ in the month of January. The corresponding figure for July is 31 minutes. In the case of minimum temperature, the lag amounts to about 60 minutes in January. There is no corresponding lag for July.

Table 9 shows the deviation of the monthly aperiodic amplitude of the diurnal range of temperature from the mean annual value at selected stations in the country. The isopleths for the mean annual aperiodic diurnal range of temperature (not corrected for periodic change) are also shown on Map 4. The basis of its distribution has been explained in the preceding discussion of diuranal range of temperature. High diurnal ranges (above 30°F) are found in the middle Indus plain, Kachhi-re-enterant and the eastern half of the quadrangle of the Baluchistan plateau. The highest range (38.8°F) is recorded at Kalat. In the Himalayas and the coastal areas the diurnal range is below 15°F. The lowest range is recorded at Manora Island (13.7°F).

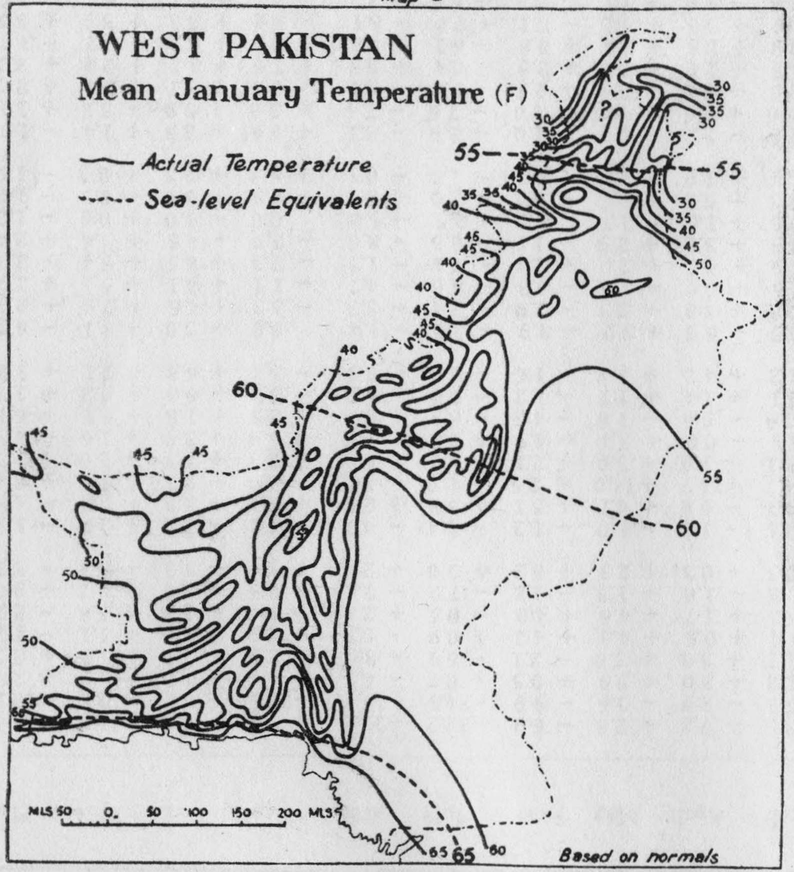
Map 1.


WEST PAKISTAN
Mean Annual Temperature (°F)
Actual temperature
Sea level equivalents
Isanomalous lines
MLS 50 0 50 100 150 200 MLS
Based on normals

Map 4.


WEST PAKISTAN
Mean Annual and
Annual Diurnal Range of Temperature
(°F)
Mean Annual Diurnal Range
Mean Annual Range
MLS. 50 0 50 100 150 200 MLS.
Based on normals

Map 2


WEST PAKISTAN
Mean January Temperature (F)
Actual Temperature
Sea-level Equivalents
MLS 50 0 50 100 150 200 MLS
Based on normals

Map 3

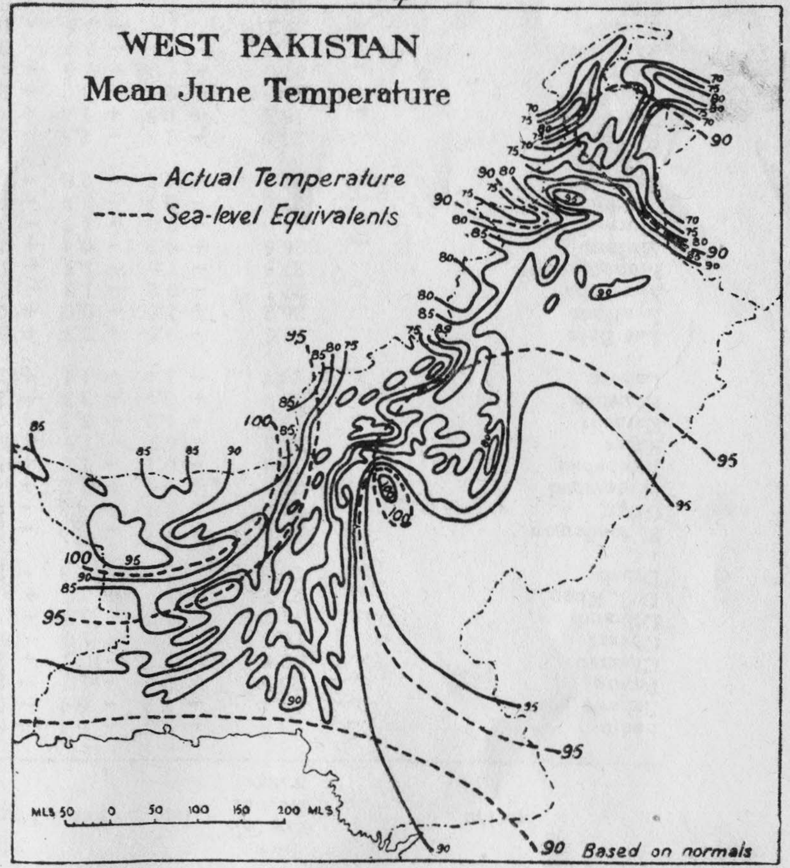

WEST PAKISTAN
Mean June Temperature
Actual Temperature
Sea-level Equivalents
MLS 50 0 50 100 150 200 MLS
Based on normals

TABLE IX

Mean monthly and annual Diurnal Range of Temperature (°F)

Station		Mean Monthly diurnal range	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Badin	...	25.6	+ 5.0	+ 6.4	+ 8.5	+ 7.8	+ 2.6	− 6.9	−12.2	−13.8	− 7.9	− 2.6	+15.7	− 6.6
Bahawalpur	...	34.4	− 5.2	− 6.9	− 5.2	− 2.9	− 3.6	− 9.9	−14.8	−15.4	−10.1	− 1.8	+ 0.8	−10.1
Bannu	...	25.1	+ 0.7	− 1.7	− 2.2	+ 3.0	+ 5.9	+ 0.5	+ 0.7	− 6.7	− 5.4	− 0.7	+ 3.8	+ 2.8
Chaman	...	30.4	−11.7	−10.1	+ 1.1	+ 3.0	+ 3.0	− 2.1	− 6.9	− 8.0	− 2.6	+ 5.7	+ 5.6	+ 2.3
Cherat	..	11.0	− 5.7	− 5.0	− 3.4	+ 0.6	+ 4.3	+ 4.2	+ 0.9	− 0.3	+ 2.9	+ 4.4	+ 1.1	− 4.1
Dilbandi	...	30.0	− 1.7	− 8.8	− 0.2	+ 1.7	+ 4.6	+ 4.0	+ 0 5	+ 2.8	+ 7.0	+ 5.3	+ 5.6	− 2,2
D. I. Khan	...	27.7	+ 1.1	− 0.7	+ 0.8	+ 1.6	+ 1.8	− 1.2	− 7.0	− 7.8	− 2.8	+ 4.6	+ 5.7	+ 3.6
Drosh	...	20.2	− 5.9	− 4.8	− 2.5	+ 0.3	+ 2.3	+ 3.2	+ 3.0	+ 2.4	+ 3.4	+ 3.3	+ 0,3	− 5.3
F. Sandeman	...	27.6	+ 1.5	− 3.9	− 2.5	− 1.8	− 0.0	− 1.3	− 3.4	− 4.7	− 1.1	+ 2.2	+ 2.7	− 1.1
Gilgit	...	19.5	− 5.9	− 4.8	− 3.1	− 0.8	+ 4.1	+ 5 1	+ 3.8	+ 2.6	+ 2.7	+ 1.3	− 0.3	− 4.8
Hyderabad	...	25.2	+ 6.5	+ 3.2	+ 4.7	+13.7	+14.0	− 2.5	− 0.0	− 2.0	− 4.9	− 2.7	+ 3.4	+ 0.4
Jacobabad	...	30.4	− 0.1	− 1.0	+ 1.1	+ 3.0	+ 3.0	− 2.1	− 6.9	− 8.0	− 2.9	+ 5.7	+ 5.6	+ 2.3
Kalat	...	38.8	− 6.7	− 7.5	−16.4	− 0.0	+ 3.3	+ 4.5	+ 1.2	+ 3.5	+ 6.9	+ 5.9	+ 1.6	− 4.8
Karachi	...	13.7	+ 4.0	+ 3.5	+ 0.9	− 0.6	− 1.6	− 4.5	− 6.3	− 6.1	− 2.5	+ 1.8	+ 6.1	+ 6.1
Khushab	...	25.9	+ 0.4	− 3.3	− 2.1	+ 1.4	+ 1.7	− 1.2	− 5.4	− 6.5	− 2.1	+ 6.0	+ 5.2	+ 3.9
Lahore	...	29.7	− 1.4	− 1.1	+ 1.2	+ 4.2	+ 3.4	− 1.6	− 8.5	− 9.3	− 3.4	+ 6.3	+ 7.1	+ 3.2
Las Bela	...	32.6	− 9.5	+ 3.3	+ 5.5	+ 6.5	+ 3.2	− 3.9	−12.0	−11.4	0.0	+ 5.0	+ 8.1	− 6.3
Lyallpur	...	26.2	+ 1.0	− 0.0	+ 2.8	+ 3.8	+ 2.3	− 1.9	− 7.4	− 8.7	− 3.3	+ 4.6	+ 7.9	+ 2.3
Miranshah	...	22.1	− 0.2	− 1.3	− 1.6	+ 9 6	+ 1.6	− 0.3	− 4.6	− 4.7	− 1 1	+ 4.1	+ 5.1	+ 2,9
Montgomery	...	27.9	− 1.6	− 1.5	+ 1.9	+ 4.1	+ 2.0	− 2.4	− 7 1	− 7.5	− 2.3	+ 6.5	+ 5.4	+ 2.0
Multan	...	26.6	+ 0.3	− 0.4	+ 1.5	+ 3.8	+ 2.5	− 1.9	− 6.5	− 8.0	− 3.9	+ 4.5	+ 5.4	+ 2.9
Murree	...	15.0	− 3.0	− 1.5	− 0.0	+ 1.5	+ 2.5	+ 2.2	− 0.5	− 1.6	0.0	+ 1.0	+ 0.8	− 1.2
Nokkundi	...	27.8	− 0.7	− 3.0	− 2.5	− 5.2	+ 6.6	+10.5	− 2.0	− 2.7	+ 2.8	+ 6.4	+ 2.3	− 1.0
Rajgur	...	28.3	− 4.0	− 2.8	− 0.4	+ 1.0	+ 1.4	+ 0.3	− 1.3	− 0.3	+ 8.4	+ 3.5	+ 2.0	− 1.6
Parachinar	...	23.0	− 1 8	− 2.5	− 1.8	− 1 2	+ 0.9	+ 1.0	− 2.9	− 3.1	+ 6.6	+ 2.5	+ 1.4	− 1.7
Pasni	...	19.3	+ 0.5	+ 1.0	+ 6.6	+ 3.6	+ 0.8	− 4.0	− 7.6	− 7.4	− 2.6	+ 3.9	+ 5.6	+ 1 1
Peshawar	...	26.5	− 2,6	− 3.0	− 2.3	− 0.4	+ 2.1	+ 2,1	− 3.0	− 5,1	− 0.6	+ 4.7	+ 5.5	+ 2.0
Quetta	...	29,0	− 7.0	− 7.6	− 4.5	− 1.1	+ 2.3	+ 2.5	− 0.4	+ 5.5	+ 7,6	+ 3.1	+ 2.2	+ 3.0
Rawalpindi	...	26.7	− 1.1	− 3.3	− 0.9	+ 1.8	+ 2,8	+ 0,8	− 6.1	− 7.8	− 2,0	+ 5.7	+ 7.2	+ 3.8
Sialkot	...	25.1	− 1.7	− 1.6	− 1.0	+ 3.8	+ 3.2	− 0.1	+ 7.0	− 8.1	− 3.2	+ 5.3	+ 5,9	+ 2.5
Sibi	...	26.8	+ 1.3	− 0.8	− 0.2	+ 1.0	+ 1.1	+18.4	− 6.2	− 7.2	− 1.7	+ 5.3	+ 6,5	+ 2.6
Sukkur	...	21.6	+ 5.1	+ 5.1	+ 7.2	+ 5.4	+ 6,6	− 5.0	− 0.2	− 1.4	+ 1.7	+ 4.6	+ 6.5	+ 5,1

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GEOGRAPHICAL RECORD

IGU REGIONAL CONFERENCE, JAPAN, AUGUST-SEPTEMBER, 1957

Japan acquired the distinction of being the 1st country to hold a regional conference in Asia from 29th August to 3rd September. It was jointly organized by the International Geographical Union and the Science Council of Japan. More than 80 delegates from foreign countries and over 300 Japanese geographers participated. Prof. Kazi S. Ahmad, Prof. Nafis Ahmad and Dr. Shams-ul-Islam Siddiqi represented Pakistan. Prof. H. W. Ahlmann, President, I.G.U. and Prof. H. H. Boesch, Secretary, I.G.U. and most of the other members of the Executive Committee were present. The Conference was divided into nine sections—Geomorphology, Multi-purpose Projects & Regional Structure of Industries, Land Utilisation, Climatology, Industrialisation, Regional Geography & Miscellaneous, Settlement Geography, Population and Hydrography. Prof. Kazi S. Ahmad presided over the section on 'Land Utilisation'.

About 125 papers were contributed to the various sections of the Conference. The delegates from Pakistan read papers on the following subjects:

Prof. Kazi S. Ahmad	—	'Canal water, problem in the Middle Indus Plain'.
Prof. Nafis Ahmad	—	'Karnafuli project.'
Dr. Shams-ul-Islam Siddiqi	—	'Physical elements of agricultural land use in the Mastung valley.'

The opening session of the Conference was held on the 29th of August at the Yasuda Hall of the University of Tokyo under the presidentship of Mr. Tomatsunaga, the Minister of Education, and was addressed by Prof. Fumio Tada, Chairman of the Organising Committee of the Conference, Professor Saiji Kaya, President of the Science Council of Japan, Prof. H. W. Ahlmann, President of the International Geographical Union, Prof. Tadao Yanaihara, President of the University of Tokyo and Prof. Dudley Stamp, of the London School of Economics.

Sectional meetings were held at Gakushi-Kaikan (University Club) Kanda, Tokyo, from the afternoon of 29th August till the afternoon of 31st August. An exhibition of modern maps was also organized at the club. A symposium on 'Geography of South-East Asia' was held on the 31st of August under the presidentship of Prof. Stamp.

Receptions were held by (1) The Association of Japanese Geographers and the Tokyo Geographical Society, (2) The President of the University of Tokyo, (3) The President of Science Council of Japan and the Chairman of the Organizing Committee of the I.G.U. Regional Conference in Japan, (4) The Governor of Tokyo and (5) The Ministry of Education. A number of local excursions were arranged to show the various aspects of the life of Japan.

On 1st September the whole of the Conference shifted to Nara, where sectional meetings were held on the 2nd and 3rd of September at the Tenri University. An exhibition of old maps was arranged at the Tenri University, and several local excursions were arranged. There was a magnificent Suki-yaki party on the 2nd of September in the Great Hall.

The closing session was held in the morning of the 3rd with an illustrated lecture by Prof. George B. Cressey on "Brown, White and Black". In the afternoon there was an excursion to Kyoto by bus where a tea party was given by the President of the Kyoto University.

In the morning of the 4th September the Conference split up into excursions III, IV & V; excursions I and II were held earlier.

The following excursions were arranged before and after the Conference:

August 19—August 27—Excursion	I	Hok Kaido
August 21—August 28—Excursion	II	Tohoku Region, North Honshu.
Sept. 4— Sept. 11—Excursion	III	Tokai and Tosan District, Central Japan.
Sept. 4— Sept. 13—Excursion	IV	Setouchi & Kyushu District, Western Japan.
Sept. 4— Sept. 9—Excursion	V	Setouchi and Shikoku District, Western Japan.

Prof. Fumio Tada made excellent arrangements for the delegates and everything was perfect. The delegates owe a great debt of gratitude to Professor Tada and his colleagues, Presidents of the universities and the Government of Japan for the great hospitality extended by them. The delegates were all much impressed by the simplicity, courtesy and artistry in Japan. This great country has not only rehabilitated itself completely from the effects of the last war but has also forged ahead, in many fields of industry. During the excursions the delegates had the occasion to see many factories and cultural institutions, which was a source of satisfaction. The delegates were presented a number of pamphlets, brochures and maps. Some of the pamphlets and maps were specially prepared in English for the benefit of foreign delegates.

ADVISORY COMMITTEE ON ARID ZONE RESEARCH

The Thirteenth Session of the Advisory Committee on Arid Zone Research was held at Karachi at the Pakistan Institute of Cotton Research & Technology on November 4, 5, 6 and 15. Professor E. S. Hills, Professor of Geology, University of Melbourne, was elected Chairman. The members of the Committee who attended the session were: (1) Albert Dr. G., Chief du Service des Sols de l'Office de la Rechersche, Scientifique et Technique Outre-Mer 1, Paris (France), (2) Behnia, Professor A., Professor of Hydrogeology, University of Tehran, Tehran (Iran), (3) Bogomolov, Professor G. V., Section of Geographical Geology, Academy of Sciences of the U.S.S.R., Moscow (USSR), (4) Greene, Dr. H., Rothamsted, Experimental Station, Harpenden, Herts (U.K.), (5) Hills, Professor E. S., University of Melbourne, Carlton N. 3 (Australia), (6) Naqvi, S. N., Director, Meteorological Service, Karachi (Pakistan), (7) Ramadan, Professor M. M., Professor of Zoology, Faculty of Science, Alexandria University, Alexandria (Egypt), (8) Thornthwaite, Dr. C. W., Director, Laboratory of Climatology, Elmer, New Jersey (U.S.A.) and (9) Batisse, Dr. M., Department of Natural Sciences, UNESCO, 19 Avenue Kleber, Paris 16 (France). The session was also represented by the F.A.O., W.M.O., W.P.C., W.H.O., I.C.S.U. and I.G.U., the latter two by Prof. Kazi S. Ahmad, Head of the Department of Geography, University of the Panjab, Lahore.

The following were the principal subjects discussed and suitable conclusions arrived at:

1. Functions, and methods of work of the Advisory Committee.
2. Activities report for the period, 1st April to 30th September, 1957.
3. Reports on projects assisted financially.
4. Report on the meeting of the Sub-Committee on salinity problems.
5. Execution of the programme, 1957-58:
   (*a*) preparation of symposium on salinity problems.
   (*b*) determination of subjects for reviews of research.
   (*c*) assistance to designated institutes.
6. Consideration of requests for assistance.
7. Role of the panels of experts.
8. Consideration of the draft programme, 1959-60.

From 12th to 14th November, the members of the Committee were taken on a study tour by Air, Karachi — Rawalpindi — Quetta — Karachi. They visited: (*a*) Rawalpindi District Soil Conservation Project Area, Rewat, (*b*) Soil Conservation and Erosion Control Project, Rawalpindi, (*c*) Taxila Museum and Excavation Sites, (*d*) Geophysical Institute, Quetta and (*e*) Sand Dune Stabilization Project, Mastung.

From 7th to 11th November, the members of the Committee participated in the symposium on "Soil Erosion and its Control in the Arid and Semi Arid Zones" organized jointly by the Food and Agricultural Council of Pakistan and the Unesco South Asia Science Cooperation Office, New Delhi.

Twenty-nine papers were contributed to the symposium. Dr. Kazi S. Ahmad's paper, written jointly with Mr. Mubashir Lall Khan, was on "Variations of Moisture Types and their bearing on Soil Erosion in West Pakistan".