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THE GEOGRAPillC STUDY OF POPULATION: SOME MEASURES OF DISTRIBUTION

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Over two decades ago, Trewartha in his presidential address to the Association of American Geographers presented the case for population geography and called for greater attention to it.[1] A year later, James had reason to believe that "the geographic study of population is an under-developed topical field."[2] He observed:

"There is need for a refinement of cartographic methods comparable to the refinement already achieved by the demographers in their statistical procedures. The fact that this must be done in the face of inaccurate and generally inadequate data should be no more of a deterrant than was this same fact for the scholars who developed the statistical method."[3]

Evidently American geographers took serious note of it, and by the time Ian Burton had announced that the quantitative revolution was over,[4] American geographers had made some notable contributions in the field of population geography, with particular reference to urban populations.

So much has been written on the limitations and the inherent weaknesses of the traditional dot and density maps that there is hardly any need for recounting *it*. Instead, I would rather repeat what Duncan said, "the basic difficulty *with* any cartographic method is, of course, that only relatively imprecise conclusions can be demonstrated with a map."[5] Here it would be pertinent to mention the pioneer work of Robinson and his associates whose major concern was to suggest a cartographic-quantitative technique that helps in explaining the mutuality that exists among the distributions of an area.[6]

The inadequacy of cartographic techniques in bringing out relationship in precise terms is no more a debatable issue. On the basis of their analysis Robinson and his associates were able to provide satisfactory solution to problems generally encountered in studies of areal association-problems related to appropriate sampling methods, to the difficulty that arises when one wishes to employ both point data and unit area data and to problems of modifiable unit. No less important is the question of how best to map departures from certain mean relationships. Robinson's study clearly demonstrates how a combination of cartographic-quantitative techniques serves to overcome the inherent weaknesses of cartographic methods in establishing relationships among phenomena in their areal setting. In passing, let me observe that it would be a serious omission if Robinson's contributions do not find a place in the list of suggested reading material of related geography courses at the Honours and Masters levels in our universities.

The past two decades have witnessed substantial addition to work of methodological nature in geography. These efforts have crystallised in the development of techniques of describing and measuring population distribution. This paper presents a synopsis of four of such measures of population distribution. These are:

1. Measures of Spacing
2. Population Potential
3. City-size distribution, and
4. Density-Distance relationship.

While reviewing these measures I have at appropriate places also mentioned the works of Pakistani geographers employing these measures. By doing so, the idea is not to project personalities but to emphasize how little we have done in this particular field.

Measures of Spacing

In the study of point distribution the major concern of a geographer is to determine the pattern of distribution. Visual impression afforded by a map are just impressions. There was therefore, need to evolve methods of measuring the spacing of population units. The first step in this direction was taken by plant ecologists working on the spacing of members of species in the plant community. Clark and Evans made use of a statistical technique known as nearest-neighbour analysis.[7] This analysis indicates the degree to which the distribution of individuals in a population on a given area departs from that of a random distribution. Briefly, the analysis proceeds as under:

For a given universe of territory containing n units (individuals or groups of individuals) of population, let r be the linear distance of the i th unit to its nearest neighbouring unit. The ri are measured for the entire population of units or a random sample thereof. Let p be the density of population units.

Iff is the mean of the r_i, then the mean observed distance fA =~ n . The mean distance which would be expected if the population were distributed at random, *if'* can be shown to have a value equal to $0.5 \sqrt{P}$. The ratio, R, of observed to expected distance R=(~~) may vary from zero to 2.1491, with a value of unity occuring for a random distribution, under conditions of maximum aggregation, R=Zero, and under conditions of maximum spacing (or uniform distribution) R=2.1491.[8]

Among the geographers Michael Dacey has done the most work on the theoretical aspect of the Nearest Neighbour Analysis.[9] Its empirical aspect was demonstrated by Leslie King in his study of the pattern of urban settlements in selected areas of the United States.[10] Over a decade ago, this writer used the Clark and Evan's Nearest Neighbour Statistic in a study of the distribution pattern of urban centres in Pakistan, which yielded interesting results.[11]

The nearest neighbour method is applicable to map analysis of nearly all natural, physical and cultural populations which have discrete spatial distributions and are mapped as points.

Population Potential

By now we are all familiar with the concept of Population Potential introduced to the geographers for the first time by John Q. Stewart, a physicist by training, some 28 years ago.[12] Preston James in his 1954 study recognized the importance of "challenging" paper of Stewart, as a device for uncovering some kind of theoretical order in the processes leading to the distribution of people.[13]

Stewart presents three primary concepts based on Newtonian physics :

1. Following the formula for gravitational force, Stewart defines demographic force as a constant times the product of two masses divided by the square of the distance separating the masses. Where the population of cities i and j, designated by Pi and P_j respectively are taken as the relevant masses, demographic force F is

$$F = G \frac{P_i P_j}{d_{ij}^2}.$$

Where G is a constant corresponding to the gravitational constant.

2. Accordingly their demographic energy by virtue of this force field is given by $E = G \frac{P_i P_j}{d_{ij}}$

3. The 'demographic potential' produced at a point i by a mass or group of individuals P at j, which may be designated Vij, is defined as a constant times the mass at J which is Pj, divided by the intervening distance, that is $V_{ij} = G \frac{P_j}{d_{ij}}$.

As a corrolary, the potential at any point produced by the entire population of any given territory is given by

$$V_i = \frac{P_1}{d_{i1}} + \frac{P_2}{d_{i2}} + \dots + \frac{P_j}{d_{ij}} + \dots + \frac{P_n}{d_{in}}$$

that is $V_i = \sum_{j=1}^{n} \frac{P_j}{d_{ij}}$

Where V_i = the representation of the total potential at place i,
P_i = the size of another place in the bounded region, and
d_{ij} = the distance separating i and j.

Thus *Vi* is a summation of the effects of all n places on place i including the effects of i itself on itself.

Stewart has computed population potentials for various areas of the world for different periods of time. Since it is possible to compute total potential for every point, and for every relevant sub-area of a nation or interregional system, it is possible to construct an isopleth map of potentials (see Fig. 1).

Duncan rightly observes that the notion of potential at a point is in principle perfectly precise, whereas the concept of density at a point is meaningless and that of density in the vicinity of a point is ambiguous. Further, while the density of any portion of a territory depends only on the number inhabiting that portion, potential at any point depends on the distribution of population over the entire territory.[14]

Stewart speaks of population potential of a point as a measure of the proximity of people to that point, as a measure of aggregate accessibility, and more simply as a measure of the influence of distant places on that point. To

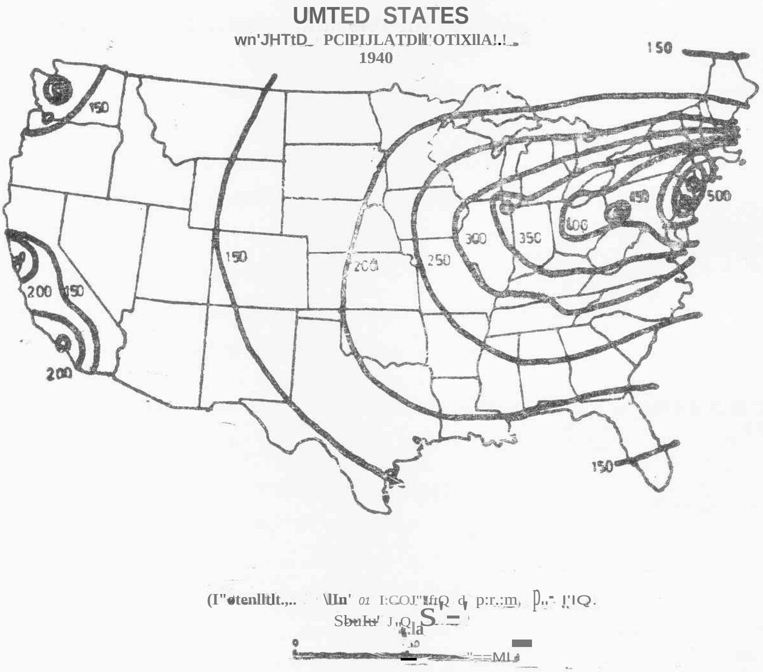


Fig. 1

point up the significance of this concept and the related concepts of demographic force and energy, Stewart and his associates conducted a number of empirical studies. He reports high correlation within the United States of the spatial variation of population potential with spatial variation in a wide variety of sociological phenomena.

Among others, these phenomena include rural population density, rural nonfarm population density, farmland values, miles of railroad track per square mile, density of rural wage earners in manufacturing, and rural death rates. In each case, as potential rises from area to area, each of those items tends to increase.

The basic issues of Gravity Model among others are those which concern the measurement of the two variables, mass and distance, the weights to be applied to the masses, and the choice of exponents for variables.[15]

In empirical studies mass has been measured in a number of ways: population, employment or regional incomes, in the study of intermetropolitan migration, volume of retail and wholesale sales, number of families, car registrations, hospital beds, value added in manufacture, newspaper circulation and school enrolment.

Similarly, distance can be measured in a number of ways: along a straight line in terms of miles, distance in terms of travel time, transport cost as in the study of industrial location. In the case of either variables, the measurement of mass or distance depends on the nature of problem being studied, the available data, and related considerations.

The issue of weights to be applied to the masses is equally critical. According to Stewart and Dodd, different weights are valid. More difficult than the selection of weights or of measures of mass and distance is the choice of exponents. Various authors hold different opinion, thereby suggesting for greater attention to the theoretical aspects of the model. Harris, in his work on industrial location uses unity for the exponents of mass and distance.

Finally, exactly two decades ago, Harris became the first geographer to have utilized the potential model in his pioneering study, "Market as a Factor in the Localization of Industries in the United States."16 He studied market potentials using retail sales per county as the measure of mass, and transportation costs as a measure of distance. Since then, the concept has been employed by scores of geographers, notably William Warntz, in the United States as well as elsewhere.

In his study of Indian Cities (1965) this writer made use of various types of potentials as measures of generalized accessibility in differentiating groups of Indian cities.[17]

A year later (1966) Iqtidar Zaidi employed market potential model in his study of "Functional Effectiveness of a State: The Case of West Pakistan,"'8 and in his subsequent study (1968) of "Locational Complementarity of Central Places in West Pakistan."19

City Size **Distribution**

Those concerned with exploring empirical regularities in the distribution of population with special reference to cities have recognized tW0 kinds of city-size distributions: rank-size and primate.

The concept of rank-size relationship owes much to the original contributions of George Kingsley Zipf who expressed it mathem:ltic:llly as follows :2,)

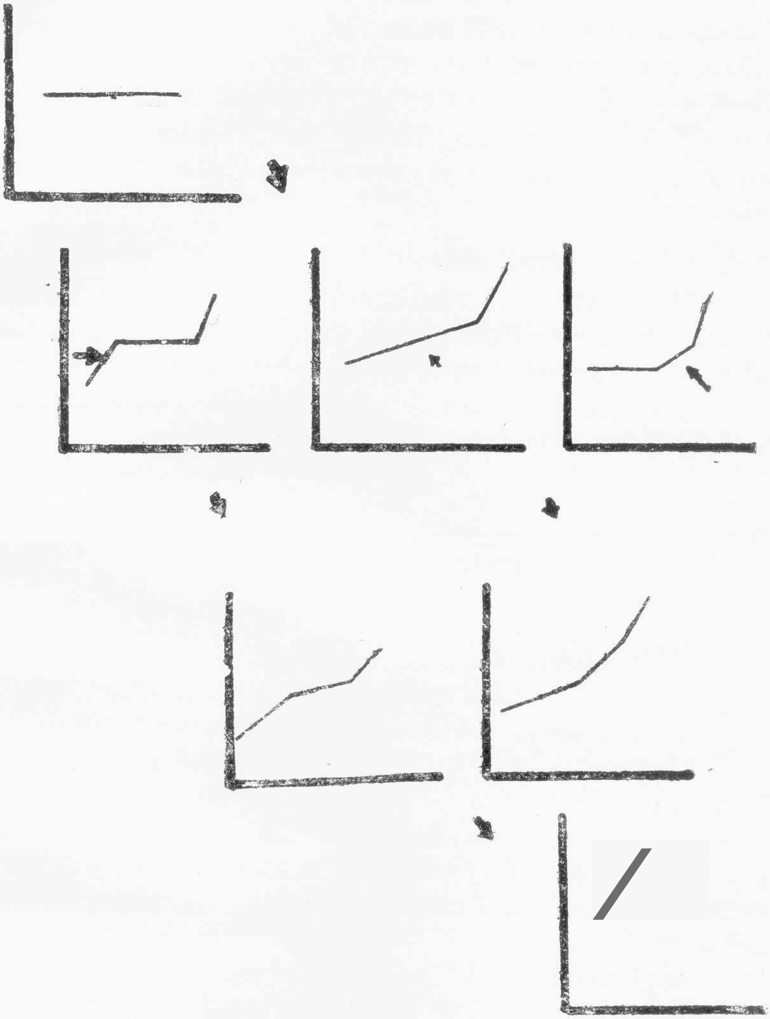
$P_r = \frac{P^I}{rq}$ which implies that the population of the r th ranking city P_r equals the population of the largest city PI divided by rank r raised to an exponent q which generally has a value very close to unity.

At roughly the same time as Zipf put forward the concept of rank-size regularity to describe the distribution of city-sizes, Mark Jafferson introduced the concept of the "Primate city."2'. He maintains that primacy is present when the largest city is several times the population of the one that is second in rank.. Later authors have applied the term to the whole distribution of cities of different sizes. Primacy, they say, exists when a stratum of small towns and cities is dominated by one or more large cities and there are fewer cities of intermediate sizes than would be expected from the rank-size rule.

In recent years Brian Berry has, through his empirical studies, added considerably to our knowledge of city-size distribution. In his well-known study, "City size distributions and economic development," Berry studied city-size distributions in as many as 38 countries from different continents excepting Africa.22 This study helped him in the formulation of a model of city-size distributions.23 The graphic model places the several types of city-size distributions on a scale between the limiting case of primacy (as in Thailand) and lognormality (as in the United States). (Fig. 2).

As an explanation of the model Berry states that it appears that there is a scale from primate to lognormal distributions which is somehow tied to the number and complexity of forces affecting the urban structure of countries, such that when few strong forces obtain, primacy results, and when many forces act in many ways with none predominant, a lognormal city-size distribution is found.

Rank-size regularities have been associated with the existence of integrate:.! systems of cities in economically advanced countries, whereas prim'lte cities have been associated with over-urbanization and superimposed colonial economies in underdeveloped countries or with political, administrative controls in indigenous subsistence and peasant societies.



Developmental model: city_size distribution

Fig. 2-a.

Berry was thus able to demonstrate the significance of the statistical regularity of city-size distributions, particularly, in relation to cities as systems within systems of cities.

Sometime ago, this writer made a study of city-size distribution in Pakistan as well as in the then existing two wings of the country, viz. West Pakistan and East Pakistan using 1951 and 1961 census data.[24] The findings of this analysis accorded well with the model presented by Berry. It was found that city-size distribution in Pakistan did not conform to the requirements of the rank-size rule. In each case (Pakistan, West Pakistan and East Pakistan) there appeared to be closer approximation of city-size distribution to primacy.

Distance-Density Relationship

More than two decades ago, the economist, Colin Clark prefaced his article on population densities with the remark that this branch of geography appeared to be relatively neglected.[25] He then demonstrated that regardless of time or place, the spatial distribution of population densities within cities appears to conform to a single empirically derived expression:

$$d_x = d''e^{-bx}$$

Where d = population density d at distance x from the city centre.

do = density at the city centre

e = natural logarithmic base

b = density gradient, indicating the rate of diminution of density with distance, a negative exponential decline.

The regularity states that urban population densities decline in a negative exponential manner with increasing distance from the city centre.

Clark studied 36 cities, all of which displayed the above-stated regularity. In recent years, Berry[26] and Newling,[27] among others, have added considerably to our knowledge of Colin Clark's initial findings. On the basis of his study of over hundred cases (cities) providing a satisfactory coverage of the world, Berry was able to confirm what Clark had established on the basis of his rather restricted sample.

As for the factors influencing density gradient Berry confirms the findings of Clark, Weiss[28] and Muth[29] that 'b' (i.e. density gradient) diminishes as size of city increases, so that smaller cities are more compact than larger.[30]

Further, it was confirmed that the time dimension also influences the density gradient.[31] Clark found diminishing gradients through time for London, Paris, New York, Chicago, Berlin and Brisbane, to quote a few. later studies revealed that this generalization was valid so far as Western cities were concerned but the same was not true of non-Western cities. In the West central densities rise, then fall; in non-Western cities they register a continual increase. In the West density gradients fall as cities grow; in non-Western cities they remain constant. Accordingly, whereas both degree of compactness and crowding diminish in Western cities through time, non-Western cities experience increasing overcrowding, constant compactness, and a lower degree of expansion at the periphery than in the West (Fig. 3). These findings are of great significance and certainly of much relevance to our understanding of systems of cities.

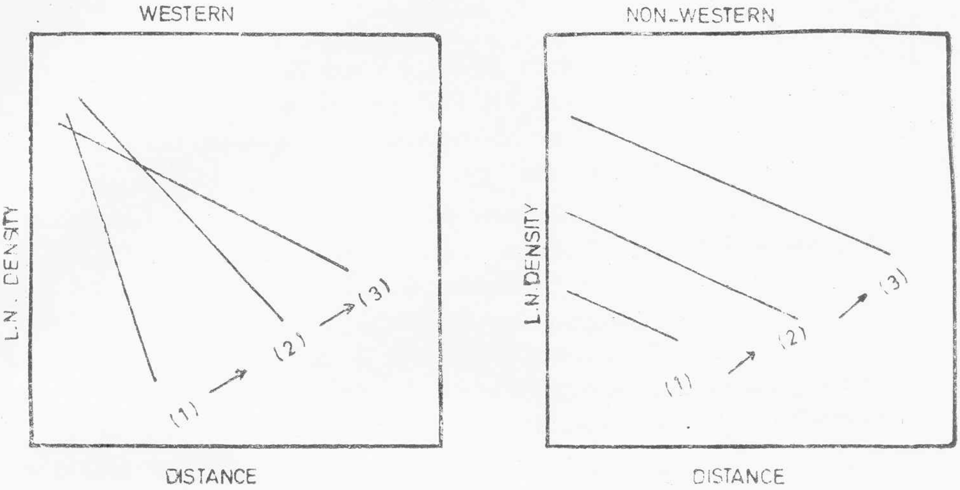


Fig. 3. Temporal comparison, Western and non-Western cities.
(time periods (1), (2), (3) .... to (n»)

In Pakistan, the only study of this nature is Zafar Hasan's analysis of distance-density relationship in the city of Hyderabad.[32] The result of his analysis both in respect of intercept and gradient accords well with the findings of Clark, Berry and Newling.

Conclusion

In conclusion, it should be recognized that population distribution is a subject that has not been the exclusive concern of geographers. Far from it, most of the advanced empirical research on this topic was undertaken by persons who belonged to other disciplines. It implies that on matters of this nature the geographer must co-ordinate his efforts with fellow workers in related fields.

The other major consideration that deserves attention of geographers in Pakistan is the advisability of making population distribution with all its wide ramifications and connections with other social sciences, the subject of concerted research efforts.

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RICE SOILS OF PUNJAB

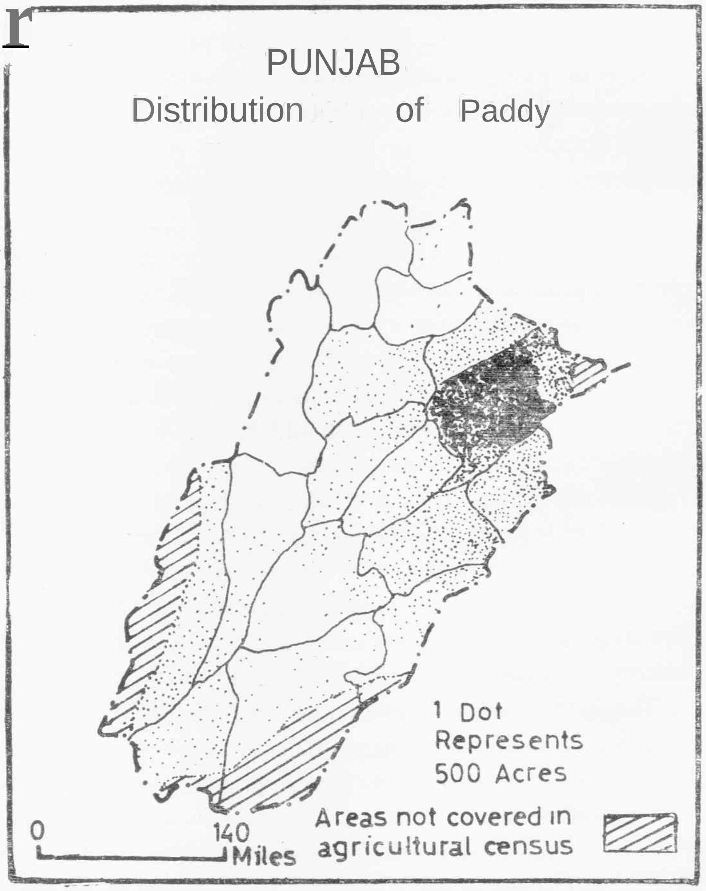
GHULAM SAEED KHAN AND ANIS AHMAD ABBASI

For centuries rice has been an important source of diet in the Indo-Pak Subcontinent. Punjab and Sind are the large rice producing areas of Pakistan. Basmati and a few other varieties of rice in Punjab are being sown due to their popularity within the country and abroad, specially in the Middle East. More and more area is being brought under the acreage of these varieties. Rice production in Punjab was 1.188 million tons in 1975-76 and 1.311 millions in 1976-77. Main factors responsible for the recent increase in the area are higher support price of paddy announced by the Government as incentive to rice growers and better water supplies. As yet Punjab's per acre average yield compared to the rest of the rice growing countries of the world is very low. In present days of advanced technological skill poor per acre production in an area where a major portion of population is involved this industry certainly needs attention. So it is in the general interest of the people, and common rice farmers in particular, to adopt such measurers as to get increased yields per acre. Such measures are usually very commonly known i.e. use of promising varieties of crops, proper management of soil and water; control of weeds, insects and pests etc. Proper soil management for a particular crop plays a pivot role in the boosting up of crop production. Hence to promote rice cultivation, which is better yielder than other crops, specially wheat, and an important source of foreign exchange, it is essential that it should be grown on soils which could provide favourable conditions for its growth.

The types of soil suitable for rice cultivation depend more on the condition under which the plant is grown than upon the nature of the soil. Its cultivation is governed rather by water supply than by the nature of soil.[2] However, the semi-aquatic conditions under which it is cultivated necessitate a heavy soil through which irrigation water will not easily percolate, for the demands of plant regarding water are more precise than are its demands on soil condition. According to Pendleton[q] rice is doubtless the most adoptable food crop if water remains on the soil until the maturing of the crop and it can produce at least a little grain on soils that are unbelievably poor in plant nutrients. Rice is tolerant of considerable variation in soil reaction (pH), it does appear to show a preference for the acid type. Soil structure, of such great importance to most crops, is of little or no significance to rice. The ideal conditions of the soil for rice is creamy and devoid of crumbs, and the underwater tillage to produce this condition in addition to suppressing weeds.[2] Puddling of soil is done to create such conditions. Fine silty and clayey soils with moderately well and poor drainage are best suited. Reasonable yields can, however, be obtained on medium textured soils as well with proper management.

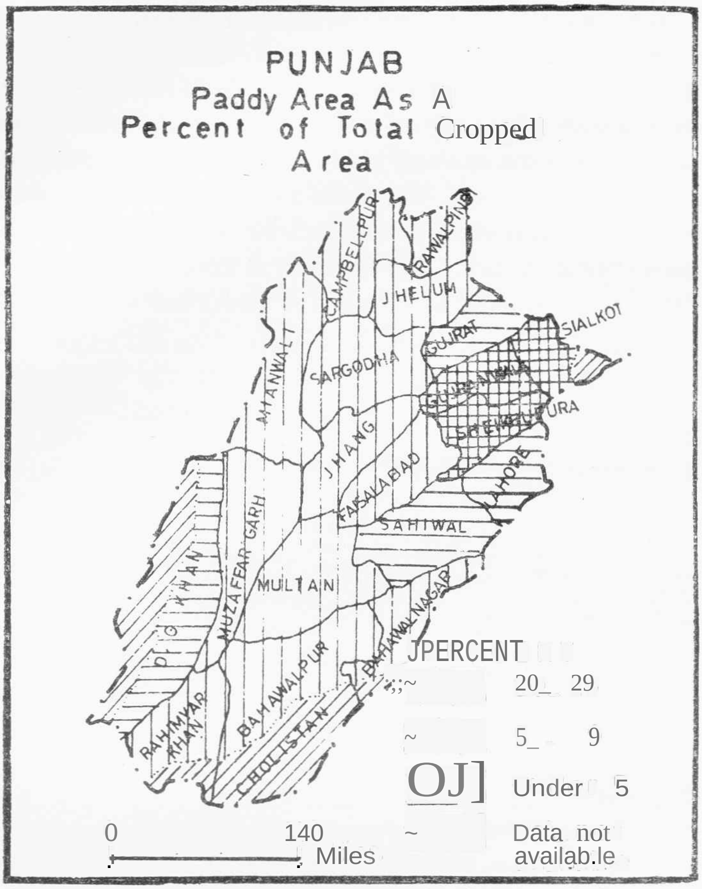
Rice Soils of Punjab

Findings of soils survey[13] revealed that there are a variety of soils in the Punjab having favourable characteristics for rice cultivation. Rice cultivation is mainly practised in the north-eastern part of Punjab (Fig. I & II) which is the best suited ecological zone. Soils of other parts of Punjab, though having favourable soil conditions, are better suited ecologically for cotton which is another kharif crop and also a foreign exchange earner for the country. The rice zone comprises a broad strip of land in the lower aprons of the Himalayan piedmont, lying between Ravi and Chenab rivers covering Lahore, Sheikhupura,



Data_ Agricultural cencus of Pakistan 1972

Fig. 1



Data_ Agricultural census of Pakistan. 1972.

Fig. 2

Gujranwala, Sialkot, and Gujrat Districts. The soil materials laid down in basins and channel infills in these areas are mostly clayey. The climate of the zone is sub-humid with rainfall 400 to 700 mm which shows two maximas, one in winter and the other in summer. On receiving a few showers the depressional sites in the submountains tracts are subject to seasonal inundation during summer rains. This area is now producing one of the world's finest varieties of rice i.e. Basmati. Though its potential yield is about half of that of coarse IRRI varieties yet its extensive market demands attract the cultivator of the region to grow Basmati rice.

Some of the important characteristics of these soils are described below:-

1. Gujranwala series

It covers about 740 sq. miles in Gujranwala, Sialkot, Gujrat and Lahore

Districts. The surface soil (Ap) ranges in colour from brown to dark brown and in texture from silt loam to loam and is generally non-calcareous.

The colour of sub-soil (B-Horizon) is from brown/dark brown to yellowish brown with or without a few fine mottles. In texture it ranges from silt loam to silty clay loam and silty clay while its structure is moderate medium to strong sub-angular blocky. Fine iron and manganese concretion may be found inter bedded. It is slightly calcareous but some profiles show absence of calcium carbonate altogether. The thickness of horizon series from 90 to 170 em. The ped faces and pores have cutans of humus and soil material.

The sub-stratum usually consists of layers of various textures and colours which are moderately to strongly calcareous and the associated material is common kankers which form as distinct zone in the soil.

SCHEMATIC SOIL PROFILE
OF
RICE SOILS OF PUNJAB

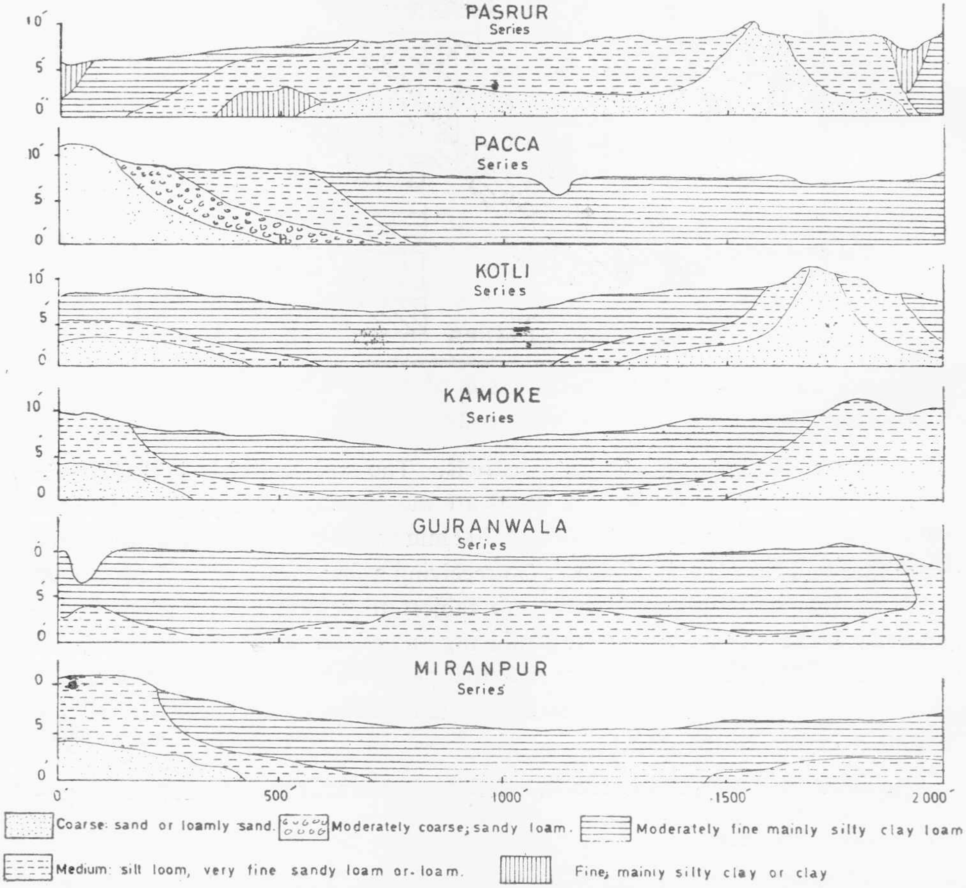


Fig. 3.

2. Kamoke series

It covers about 360 sq. miles in Gujranwala, Sialkot and Lahore Districts. The surface soil (Ap-horizon) is greyish brown to dark greyish brown or brown, dark brown in colour. The common soil texture is from silty clay loam to silt loam or clay loam. Mottles are generally present. The surface soils contain in some place small amount of calcareous material.

The sub-soil (B-horizon) are olive grey to greyish brown and dark brown in colour. Silty clay loam to silty clayey material constitutes the dominent texture. Structure is moderate to medium and coarse sub-angular blocky and have patchy cutans on ped faces with some slikensides. The soils is non-calcareous however, some areas within may show slight calcareous patches. Fine iron and manganese concretions may also be found. The thickness of horizon varies from 90-115 cm.

The (C-horizon) may have different layers of varying texture and/or colour. A zone of lime accumulation, containing kankers, is usually present.

3. Kotli series

It covers about 354 sq. miles in Gujrat, Gujranwala and Sialkot District. The surface soil (Ap-horizon) ranges in colour from dark greyish brown to brownish grey. The texture varies from silty clay loam to silty clay and clay. The thickness of this horizon varies from 8 to 15 cm. and is non-calcareous.

The sub-soil ranges in colour from very dark greyish brown to dark greyish brown showing weak but definite gleization. In texture it varies from silty clay to clay; structure is weak to moderate coarse sub-angular blocky with common intersecting slikensides on ped faces. It is slightly calcareous in some places while in other carbonates may be absent altogether. The thickness of sub-soil is about 70 cm. It has mottles with fine iron and manganese concretion. A zone of lime accumulation is usually present at about 40 cm depth. The upper part of the sub-stratum is almost non-calcareous.

4. Pasrur series

It covers 107 sq. miles in Gujrat, Gujranwala, and Sialkot District. The surface (Ap-horizon) has brown/dark brown to brownish grey material. The horizon is generally free from calcareous material, however, slight calcareousness can be observed in places. The texture of horizon is represented by silt loam, silty clay loam and clay loam.

The sub-soil (B-horizon) ranges in colour from brown/dark brown to dark yellowish brown with dark greyish brown cutans. In texture it varies from silty clay loam to silty clay and clay. The structure is from moderate fine to medium blocky and sub-angular blocky, with cutans on ped faces and pores and slikensides. Yellowish brown mottles may also be present. The horizon is mostly non-calcareous and a few iron and manganese concretions occur in a scattered form. The thickness of the horizon varies from 120 to 145 em.

The sub-stratum (C-horizon) comprises of layers of various textures which show interbedded some of moderate to strong clacareous material.

5. Pacca series

It covers 87 sq. miles in Sheikhupura, Gujranwala, Sialkot, and Lahore Districts. The surface (Ap-horizon) which is 10 to 15 em. thick, ranges in colour from dark greyish brown to very dark greyish brown. Clay loam to silty clay loam and silty clay constitute the usual texture of this horizon. The mottles are fairly visible and the soil is moderately calcareous. The soil exposed at different places shows different depths which usually rangG from 30 to 90 em. and is generally composed of silty clay to clayey material, which appear dark brown to very dark greyish brown.

The sub-soil (B-horizon) ranges in colour from dark brown to very dark greyish brown common fine mottles; in texture from silty clay to clay; structurally it appears from weak coarse or medium to moderate coarse sub-angular blocky with thin patchy cutans and slikensides on ped faces. Drilling data reveal moderate to strong calcareousness at different places occasionally kankers and fine iron and manganese concretions appear in the horizon.

The sub-stratum may have laminated layers of various textures and in some places fine kankers and concretions of iron and maganese may be present.

6. Miranpur series

It covers 404 sq. miles in Gujranwala, Sialkot and Sheikhupura Districts. The surface soil (Ap-horizon) ranges in texture from silty clay loam to silty clay and clay which are dark grey to very dark greyish brown in colour. The calcareousness varies. The soil may be slightly calcareous in certain places and in other places it may be completely free of calcareous material.

The sub-soil (B-horizon) ranges in colour for very dark greyish brown to brown dark and texturally silty clay loam to silty clay and clay from length of material. Structurally having it is weak moderate medium and coarse angular or sub-angular blocky having thin broken cutans and is mottled. It shows a slight calcareousness in some places while the adjoining area may be free of calcareous mlterial. Kankers m1Y occur in lower parts. Fine iron and manganes econcretion may also be present. It varies in thickness from 60 to 110 em.

The sub-stratum usually contains layers of various textures which are generally associated with lime and iron-manganese concretions.

The other suitable soils for rice cultivation are Sagar (54 sq. miles) Shakargarh (71 sq. miles), Theri (39 sq. miles), Rustam (13 sq. miles) and Kunjah (85 sq. miles) series. These soil series ha'/e limited areal distribution in this zone. Field studies and Laboratory data shows that Miani (361 sq. miles), Bahalike (27 sq. miles), Malik (68 sq. miles) and Shahpur (25 sq. miles) series are also suitable for rice cultivation, and can equally compete with wheat cultivation which has rather better prospects. These and certain other soil associations which are scattered all over Punjab are better suited for rice cultivation but the environmental conditions are less favourable.

(c) Rice as Reclamative Crop

In Punjab Paddy is also usd as a reclamative crop on salt affected soils, which are not uncomm'Jn in this area. The cultivation of wet rice, either alone or in combination with green manuring or other soil amendments, has proved in many instances to be a useful and economic remedy for the different kinds of salinity and alkalinity found in the soil.[14] The main adverse effects of salinity on soil properties, viz., the high osmotic value of the soil solution, the high exchangeable sodium percentage and the high pH value are generally rapidly counteracted as a direct result of wet rice cultivation of crops other than rice. It has already long been found that the pH value of flooded soils changes considerably during flooding period and is lowered in case of soil having high pH values .[6, 9] McNeal *et a!.S* had concluded, after experimenting with saline-alkali and alkali soils from Pakistan, that rice cultivation indirectly facilit:les the removal of exchangeable sodium by enhancing hydraulic conductivity or by increasing the cross-sectional area serviced by the conducting pores. The question however, whether rice has significant direct effect, as a result of dissolving action of CO_2 generated by the roots, on the release of Ca from CaCO,. This possibility however, cannot be ruled action, out as due to flooding, huge amount of CO_2, evolved as a result of bacterial action accumulate because of a drastic restriction of diffusion of gases in flooded soils.[9] This increase in partial pressure of C02 will definitely have dissolving effect on the $CaC0_3$. Dissolution of only one per cent $CaC0_3$ in the soil may amount to 31 tons of gypsum per acre foot.[3]

Soils of Kala Shah Kaku Rice Research Institute

Kala Shah Kaku Rice Research Institute which carries out research on rice exclusively in the province, was opened in February, 1926, is spread over 625.09 acres out of whcih only 70.62 acres are under Rice experiments and studies.[II] The detailed soil survey[12] of the Institute area shows that the dominant soil series are Satgarh, Miani and Dungi. The other series found within the institute premises are Pindorian, Sindhelianwali, Sultanpur, Shahpur, Nabipur, Jhakkar, Shahdara, Gandhra and Gujiania series. Amongst these Miani, Nabipur, Pindorian, Shahpur, Shahdara and Sultanpur are normal soils, while the rest are saline-alkali soils. Amongst the normal soils only Miani and Shahpur series can be called true rice soils but they occupy a limited area of the rice research institute. The rest of the normal soils, occupying comparatively less area, are suitable for general cropping. As discussed earlier these soils do not truely represent the rice soils of the area hence the desired results of obtaining b~tter varieties and better yield in limited area may not prove very encouraging.

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POPULATION DENSITY AND DISTRIBUTION IN LAHORE

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Like other great cities of the world the urban reality of Lahore is a spatial, demographic, social, economic and cultural reality which is not confined to the boundaries of its politico, juridical units (like wards, municipalities). Lahore today.is no longer a town but a veritable metropolis, almost a region.

Its population has been increasing eversince the last century and will continue to increase if the present trend persists. The rate of increase is determined by factors that affect the natural increase, excess of births over deaths, and of immigration into the city.

Since 1947 there has been a remarkably large inflow of immigrants. Growth in numbers due to migration has varied considerably over the period, but the greater part of the gain spread over four clearly defined periods; and they are the 1931, 1941, 1951 and 1961 period. The rate of immigration into Lahore has varied considerably according to the changing economic conditions, and the greatest influx of population coincides with periods of economic expansion and growth. Lahore, being situated close to the Indian border, received a large number of immigrants during the intercensal period 1941-51 in the wake of the Partition of the Sub-Continent. Many of them settled here as they came from large urban centres of the Indian Provinces whereas others made their way to other areas of the province. The location of emergency refugee camps near the urban area further crystallized this tendency. This caused an acute shortage and the large number of immigrants strain on housing, services and employment in the city. Although this migration was a two way movement, the number of people migrating to Pakistan was much larger than those leaving for India. Besides the huge migration which took place along the borders, large number of people migrated to Lahore from the rural areas in search of livelihood. These factors added to the prevalent overcrowding of the city and the density and distribution of population. Although the slums had been existing in Lahore prior to Independence but the migration of refugees, influx from rural areas, increase in the number of Government officials, businessmen, educational and health institutions, skilled and unskilled workers, further accentuated the problem considerably. The degree and pace of population concentration in Lahore can be appreciated by examining population change in the rapidly growing city.

The centripetal migration from the rural areas to the city continues unabated but now there is an equally powerful centrifugal wave of migration from the city to the suburbs as the city is undergoing rapid expansion and growth both in its population and physical structure. Lahore has thus experienced the same suburban boom, which most of the metropolitan areas have experienced and has spread into the rural areas in the same way.

The population of 202964 in 1901[1] increased to 1296477 by 1961[2] Assuming that during he last six decades the net population rise is the result of many complex factors such as excess of birth rates over deaths, immigration versus emigration, changes in the structure of age groups, and composition of population according to economic status, then if the average growth rate continues to persist, it may be said that Lahore will have a population of 6.6 million by 2001 A.D. The projected population has closely coincided with the 1972 provisional data provided by the Census Organisation of Pakistan. Thus it appears that the projected population might even coincide with the population figures of 2001 A.D.

The city reveals the presence of two phenomena, first the existence of a strong homogeneous polygon of high density and intense urbanisation including the city centre (old city) and its adjacent areas. These have respectively been termed here as 'Nuclear' and 'Peri-nuclear' zones. The second phenomenon manifests itself in a series of suburbs, satellite localities and colonies; termed as the Fringe; strictly localised initially, but exploding now and overflowing and spreading out of their original limits and finally being assimilated and made contiguous with the central city. This situation began manifesting itself since the time when the walled city reached a saturation point, at least in its capaci~y in the movement of population into the neighbouring areas in the search for less congestion, more privacy and be near employment and social areas at the same time. The pulsations of exurbanisation shows a constantly changing pattern of land occupance; areas of high, moderate or low densities and clustered to scattered population distribution.

Density of Population

Density measures indicate a relationship between a given area of land or floor space and population. Density has been studied by the Master Plan Office and maps prepared according to the 1961 figures. An attempt is now being made to measure wardwise density with the help of the most recent population figures of 1968[3] and 1972[4] to make a comparative study.

The first and the most important inference drawn from the maps is that there has been change in the density of a large number of wards due to the explosion of the core, immigration, natural increase and inter-urban movement (although no estimates have been made of their relative contributions) reflecting changes in the migrants occupation in their prosperity, their social status, and in their housing requirements. The urban explosion shows that various areas of the city appear to undergo a regular sequence of growth, stability, and absolute decline as the city's expansion throws its crest outwards to the Urban Fringe (Figures 2, 3, 4). Thus Lahore seems to be growing more by what Mabogunje[5] refers to as "spatial expansion" than by "fission" in the central city. Of the sixty wards of Lahore, sixteen has experienced increase in population density, thirteen decline and thirty-one have remained constant in density. Before delving into further details, it is clear from the areal pattern of population density that there is decrease in density along a traverse from the centre to the periphery and is related to the intensity of residential land use.

High densities found in Lahore have grown outward [rom the core incorporating in its expansion old centres which were once separate and independent. They being Baghbanpura, Kot Khawaja Saeed, Shahdara, Sanda Kalan, Nawan Kot, Pakki Thatti, Moghalpura, Dharampura, Ichhra and Model Town and several other smaller scattered areas. An indication of the urban sprawl is given by the maps, which depict the rapidity of areal expansion and infilling of the outlying Wards, they being Pakki Thatti, Ichhra, Jamia Ashrafia, Baghbanpura, Dharampura, Moghalpura etc. that grew up tremendously during the sixties and now constitute integral part of the Urban Fringe with two thirds of Lahore's population.

There has been depopulation of the thirteen Wards of Lahore, they are Krishinnagar, Mozang, Landa Bazar, Islamia College, Shah Abul Muali, Beadon Road, Gawal Mandi, Sant Nagar, Said Mitha, Yakki Gate, Akbari Mandi, Mochi Gate and Lohari Gate. Of these Lohari Gate, Mochi Gate, Akbari Mandi, Yakki Gate, Gawal Mandi, Said Mitha, Beadon Road and Mozang are old business and commercial centres with diminishing rate of in-migrants and outward migration of the population due to inadequate ventilation in buildings, lack of privacy satisfactory to the residents and diminishing degree of living space depict living conditions in Burgess's area of transition,[6] where the unregulated conspite for space has driven residents to upper storeys of the buildings and from the streets only a commercial facade is visible, but from above a jumble of extra legal subdivisions can be seen. So is the case on the Mall Road which is an area of mixed commercial and non-commercial land use and locationally separates the whole-sale and retail heart of the city in the north from the surrounding residential neighbourhoods and heavy industrial districts to its south. Present are such intensive non-retail activities such as light manufacturing and professional organistiaonal services and reta'ling of consumer goods.

TABLE I

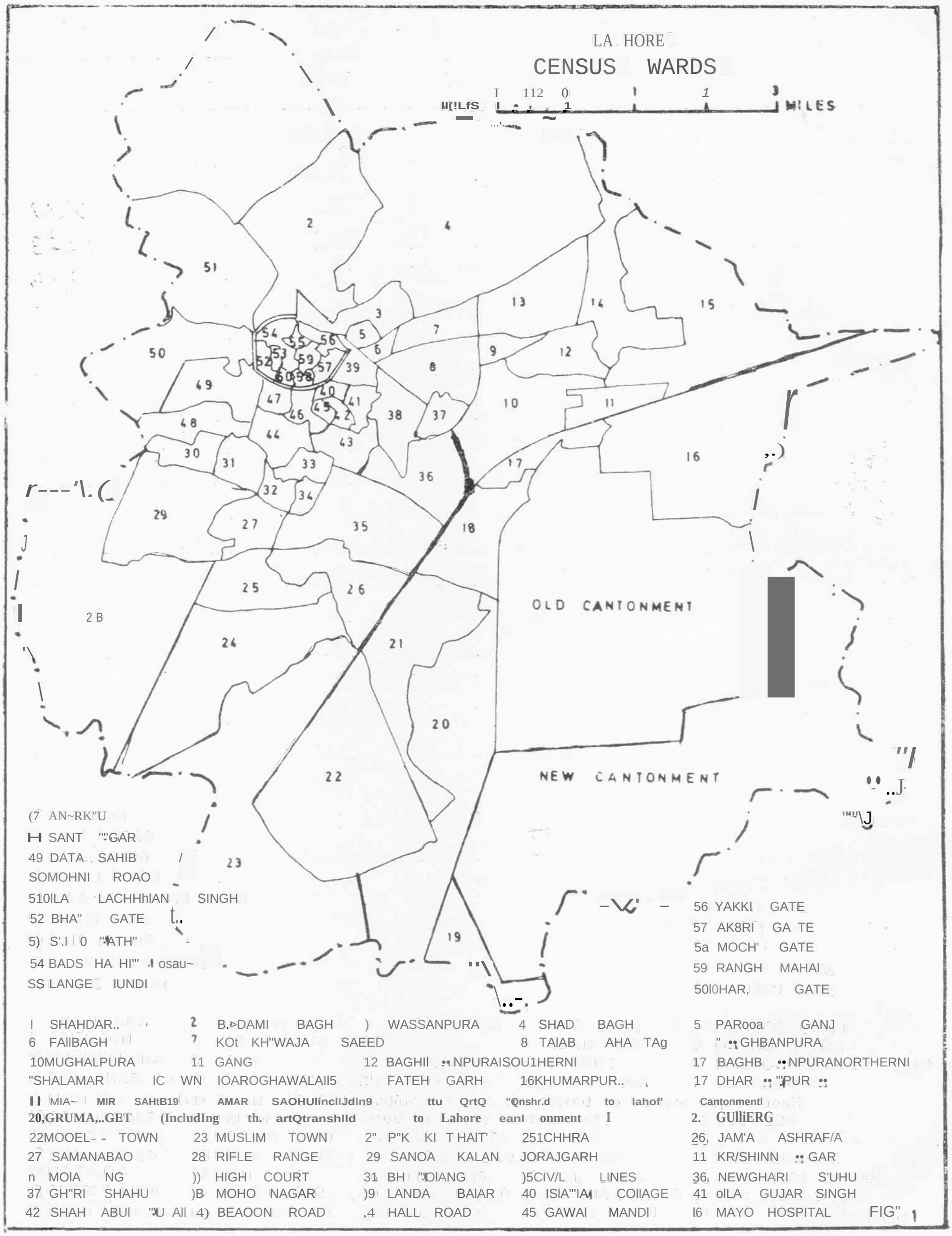
DENSITY OF POPULATION 1968 AND 1972

Ward No.	Name of Ward (Union Committee)	Area (Acres)	Population Estimate 1968	Census Population 1972	Density Per Acre	
					1968	1972
1.	Shahdara	3624	32,065	62,189	9	17.16
2.	Badami Bagh	]936	34,035	44,892	17.5	823.19
3.	Wassanpura	448	31,381	30,906	70.04	68.98
4.	Shad Bagh	5760	37,503	60,714	6.5	10.54
5.	Farooq Ganj	68	27,815	26,220	409.04	385.68
6.	Faiz Bagh	72	33,236	29,910	461.62	415.41
7.	*Kat* Khawaja Saeed.	320	31,548	35,766	98.58	111.77
8.	Tezab Ahata	632	37,399	36,744	59.17	58.41
9.	Baghbanpura	168	24,026	28,464	143.01	169.42
10.	Moghalpura	1144	23,672	35,880	20.69	249.17
11.	Ganj	380	28,485	34,764	74.96	91.48
12.	Baghbanpura (Southern).	568	25,854	37,776	45.42	66.50
13.	Baghbanpura (Northern).	872	26,331	38,490	30.19	44.14
14.	Shalamar Town (Daroghawala).	940	30,159	42,288	33.14	44.99
15.	Fateh Garh	2630	33,968	39,846	12.9	15.15
16.	Kumharpura	3032	34,936	58,122	11.52	19.17
17.	Dharampura	660	30,055	38,820	45.5	58.82
18.	Mian Mir Sahib	888	26,456	35,096	29.79	3947
19.	Amar Sidhu (excluding area transferred to Lahore Cantt.)	624	3,678	12,588	5.89	20.17
20.	Grumangat (excluding area transferred to Lahore Cantt.).	2808	24,643	53154	8.77	18.93
21.	Gulberg	2848	24,447	32,370	8.58	11.36
22.	Model Town	2880	25,780	54,402	8.95	18.89
23.	Muslim Town	4384	24,759	36,330	5.64	8.29
24.	Pakki Thatti	2200	32,267	59,862	14.66	27.21
25.	Ichhra	672	30,748	54,684	45.75	81.37
26.	Jamia Ashrafia	824	31,517	44,808	38.24	54.38
27.	Samanabad	400	23,783	32,520	59.45	81.30

Table I.-Contd.

Table I-Contd.

Ward No.	Name of Ward (Union Committee)	Area (Acres)	Population Estimate 1968	Census Population 1972	Density Per Acre 1968	1972
28.	Rifle Range	3560	42,637	63,840	11.97	17.83
29.	Sanda Kalan	1328	35,443	55,920	26.68	42.11
30.	Rajgarh	256	27,654	32,382	108.02	126049
31.	Krishannagar	280	28,672	24,732	102.4	88.33
32.	Mozang	144	21,586	22,608	149.9	157.00
33.	High Court	144	19,814	18,252	137.59	126.75
34.	Bh. Mozang	92	19,892	17,466	216.21	189.85
35.	Civil Lines	1264	18,865	19,332	14.92	15.29
36.	New Garhi Shahu	728	21,885	27,714	30.06	38.06
37.	Garhi Shahu	184	22,757	24,948	123.67	135.59
38.	Mohammad Nagar	408	28,720	30,714	70.39	75.28
39.	Landa Bazar	144	31,645	20,118	219.75	139.71
40.	Islamia College	64	22,848	16,050	357.01	250.78
41.	Qila Gujjar Singh	168	26,939	23,334	160.03	138.89
42.	Shah Abul Muali	96	19,571	15,414	203.86	160.56
43.	Beadon Road	128	26,658	25,656	208.26	200.44
44.	Hall Road	304	25,184	18,240	82.84	60.00
45.	Gawal Mandi	40	28,758	18,618	718.95	4651045
46.	Mayo Hospital	136	24,203	20,832	177.96	153.18
47.	Anarkali	124	23,082	18,636	186.14	150.29
48.	Sant Nagar	384	22,771	2,334	59.29	6.08
49.	Data Sahib	504	33,063	38,766	65.60	76.92
50.	Mohni Road	1208	26,416	35,970	21.86	29.78
51.	Qila Lachhman Singh	1624	32,215	71,280	19.83	43.89
52.	Bhati Gate	73.6	22,060	20,322	29.97	276.11
53.	Said Mitha	57.8	24,525	21,294	424.30	368 Al
54.	Badshahi Mosque	202.68	33,445	28,440	165.01	140.32
55.	Lange Mandi	31.10	22,185	16,392	713.34	527.07
56.	Yakki Gate	105.54	25,563	19,146	242.21	181.41
57.	Akbari Mandi	77.6	22,021	20,370	307.55	262.50
58.	Mochi Gate	52.9	22,448	16,902	424.34	319.51
59.	Rang Mahal	87.1	23,877	19,998	274.13	229.59
60.	Lohari Gate	43.1	24,828	20,832	576.05	483.34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31 BH "OIANG
)5CIV/L LINES
36, NEWGHARI S'UHU
37 GH"RI SHAHU
)B MOHO NAGAR
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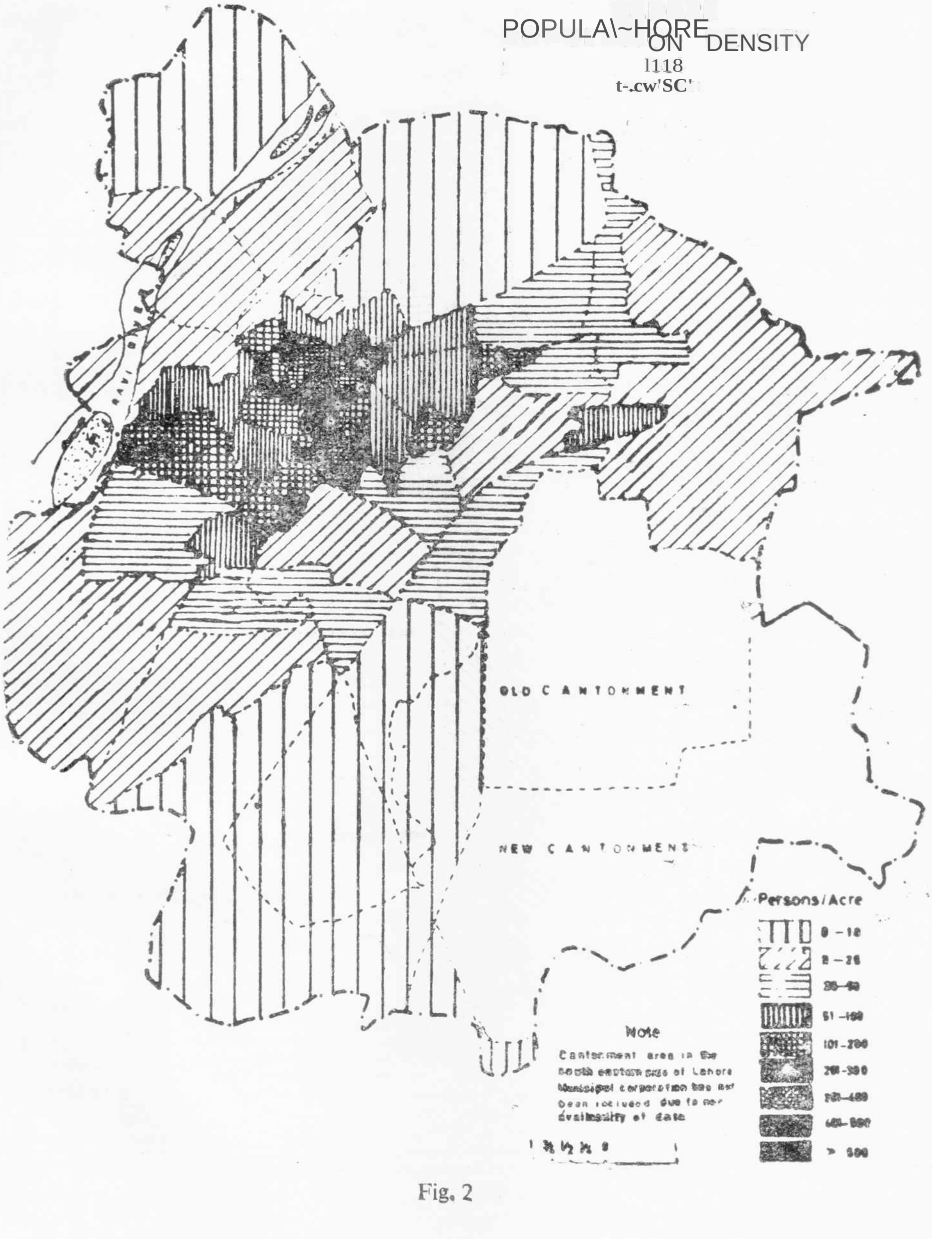
FIG" 1

Fig. 1


POPULA\~HORE ON DENSITY
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RAVI
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NEW CANTONMENT
Persons/Acre
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11 - 25
26-50
51 -100
101-200
201-300
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401-500
> 500
Note
Cantonment area in the south eastern part of Lahore Municipal corporation has not been included due to non availability of data
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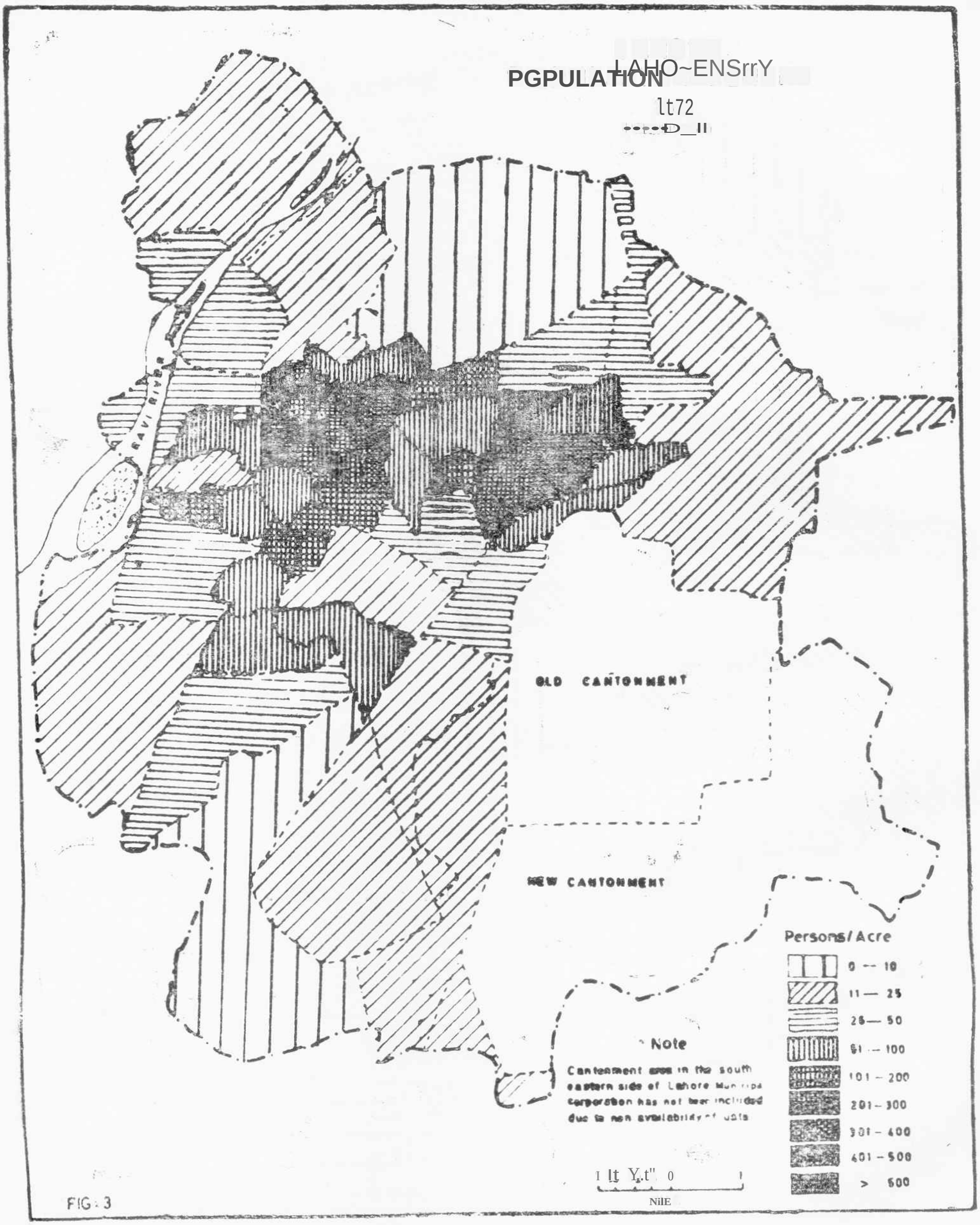
Fig. 2



Note

Cantonment area in the south eastern side of Lahore Municipal Corporation has not been included due to non availability of data

FIG : 3

Fig. 3

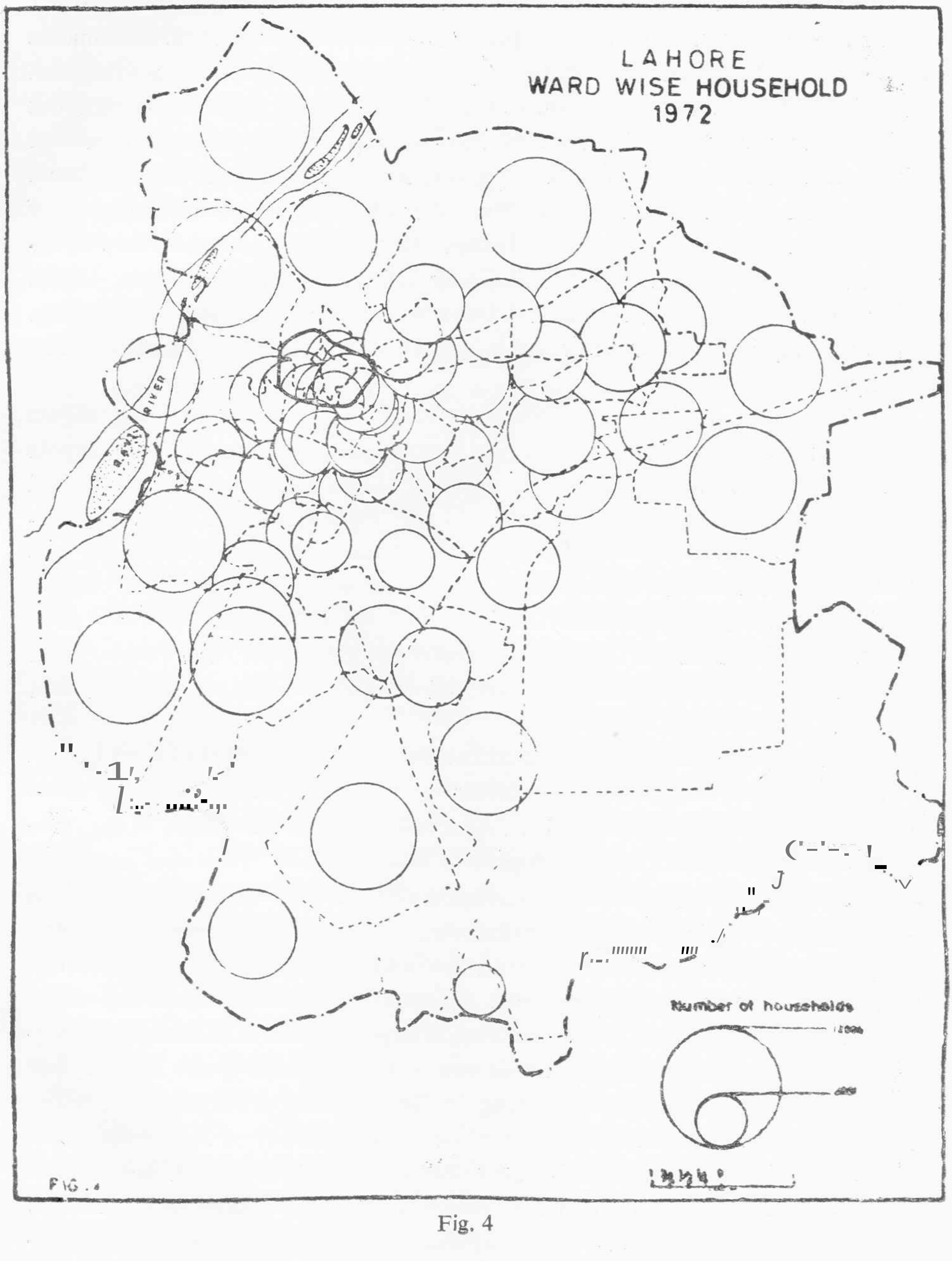

LAHORE
WARD WISE HOUSEHOLD
1972
RAVI RIVER
Number of households
FIG. 4

Fig. 4

From the data available and from interviews and experience it is evident that a number of migrants have moved from the central city due to factors already discussed and from the rural areas in search of employment, education and other commuting facilities. The maps appear to be consistent with these assessments for they indicate a phase shift in the migrant allocation pattern, suggesting that the migration stream into the core remained constant for quite some time but is diminishing as is seen from wards, Said Mitha, Lohari Gate, and Akbari Mandi and immediate Fringe area of the core from wards Gawal Mandi, Islamia College, and Landa Bazar. Thus the economic forces have shifted locus of population to concentrate in more distant areas. With the result there is decrease in population density from the Inner Urban Fringe to the Outer Urban Fringe and density decreases with increasing distance from the central city. These recently built up areas of the fringe are comparatively homogeneous in density.

The lower land values encourage comparatively lower intensity of use away from the city centre, particularly as less intensive land uses cannot compete effectively for the more expensive inner sites. This applies to the use of land for residence as well as for other purposes, and lower residential land use intensities produce lower den~ities of population towards the peripheries of the city. (This is also clear from Figures 2 and 3). The most expensive land lies close to the city centre where accessibility is provided by converging transportation routes. The further a site from the city centre the greater are the transpOl t costs involved in its use, but because of reduced competition the cost of such sites is lower.

The poor find transportation costs a more important part of their budget than do rich, and they tend to lie closer to the centre where they have more immediate accessibility to their jobs. As a result they cannot afford to consume relatively large amounts of this expensive land for their residential purposes, and so live at higher densities in small houses, where2.sthe rich can afford the time and the cost for a longer daily distance travel from tte periphery to the city centre. This factor too tends to prod uce falling land and popula ion ratios from the Nucleus to the Fringe wards. Economically, the fringe is dependent upon the central city for its economic base as explained above. Demographically it is characterized by a relatively low density of population (Figures 2 and 3) but a rapidly increasing population owing to the addition of migrants from the central city specially from wards Said Mitha with a density of 368 persons per acre in 1972 from 424 in 1968, Yakki Gate with 181 from 242, Akbari Mandi with 262 from 307, Mochi Gate 319 flom 424 and Lohari Gate 483 from 576. Other wards lying outside the walled city but very close to it with declining population are Krishannagal 88 from 102, Bh. Mozang 189 from 216, Landa Bazar 139 from 219, Islamia College 250 from 357, Shah Abul Muali 160 from 203, Beadon Road 200 from 208, Gawal Mandi 465 from 817 and Sant Nagar 6 from 59. The largest movement outward is shown by Gawal Mandi[7]. Figures 3 shows that the greatest density is found in the Gawal Mandi and Faizbagh wards outside the walled city, they being old centres. Socially the Urban Fringe is predominantly a mixture of middle class and high class people with a high percentage of households.[8] In the census a household is defined as "a collection of persons living and eating in one mess, with their dependent relatives, servants and lodgers who normally reside together". Figure 4 shows the distribution of households by means of proportionate circles. The large circles in the Fringe indicate the large number and widely spaced houses whereas the small circles indicate the small number of very closely spaced houses. Its effects are visible from the northern, eastern, southern and western parts of the city (Figures 2 and 3). Residential density clearly shows that the walled city has the largest density of houses, coinciding with the largest population density. Outwards from the Nucleus both population density and residential density go on decreasing.

In the north Shahdara has increased in density from 9 persons per acre to 17 due to the coming up of new housing schemes and the development of industry there. Shahdara has attracted population mainly from the northern rural parts to its developing industry.

In the east Fateh Garh and Kumharpura form a large homogeneous area with a low density of 12.9 persons per acre and 11.52 persons per acre in the extreme eastern part of the city. The density rises inwards as one approaches the inner parts of the city; Figures 2 and 3 show that there has been rise in the density of wards Tezab Ahata, Baghbanpura (Northern), Shalamar Town (Daroghawala), Fateh Garh, Kumharpura and Mian Mir Sahib with the largest pura being density in Baghbanpura being 143 persons per acre and the lowest in Kumharpura being 11.52 persons per acre.

To the south Muslim Town, Samanabad, Rifle Range, Sanda Kalan, Rajgarh, Mozang, High Court, Civil Lines, New Garhi Shahu, Garhi Shahu, Mohammad Nagar, Qila Gujjar Singh, Hall Road, Mayo Hospital and Anarkali have risen in density with the highest in Anarkali being 186 persons per acre and lowest in Muslim Town with 5 persons per acre. A large homogeneous area of low density of 11.25 persons per acre covers the Civil Lines, Gulberg, Gurumangat (excluding area transferred to Lahore Cantt), Amar Sidhu (excluding area transferred to Lahore Cantt) and Model Town wards. The rest of the wards of the south lie north of these wards and increase in density towards the Inner Urban Fringe.

West wards Sant Nagar shows decrease, Data Sahib shows constant density and Mohni Road, Qila Lachhman Singh show increase.

Distribution of Population

While the spatial distribution of absolute population presents some aspects of the picture and not its totality, the land and population ratio *(LIP)* will present a clearer pattern of the population distribution in Lahore and will eliminate the error of 'varied sizes' of different wards-a factor which either inflates or deflates population figures. Hence *LjP* ratio has been used to measure the degree of population concentration in different parts of the town.

With the help of this technique, the area of the different wards has been calculated in % age of the total area of the city. The wardwise population figures are also similarly represented in % of the total population of the town. This has been done just to bring the area of the wards and the population figures to a common denominator and to calculate the *LIP* ratio of each ward. Theoretically the optimum population distribution in any urban community should be uniform throughout the City and 1% of the land should accommodate 1% of the population of the town and thus the ideal ratio of *LIP* is 1: 1. But this optimum condition is ralely found and the ratio in actual distribution shows varying degrees of departure from the optimum and thus indicate comparative concentration in the ward.[9]

The spatial distribution of population in Lahore has been analysed and it is found to be far from being ideal. The *LIP* ratio is maximum in ward Yakki Gate where it was 1: 97 in 1972. In other words the ward accommodates about 160 times the number of people that it should ideally accommodate. It is one of the oldest settled residential areas of the city. Lohari Gate ward also has high concentration of population with a *LIP* ratio of 1: 12.71. This ward is also denoted predominantly residential, business and commercial area with the size of houses being small and falls into the oldest inhabited areas of the city. Ward Farooq Ganj, Faiz Bagh, Islamia College, Said Mitha, Bhati Gate, Akbari Mandi, Mochi Gate, Rang Mahal all have high population concentrations of 1: 14.2,1: 17.10,1: 12.81,1: 15.10, 1: 10.50,1: 10.50, 1: 15.55, 1: 10.00 respectively. Of them wards Mochi Gate, Bhati Gate, Akbari Mandi and Rang Mahal lie in the core and are the earliest settled wards serving at the same time as business, commercial and residential areas. Ward Faiz Bagh and Farooq Ganj lie outside the walled city and have high population concentration as they are residential in nature. A number of wards have *LIP* ratio rangeing between 1:1.04 to 1.10.00. They are the administrative lesidential business and commercial areas (Table II). Those with the lowest *LIP* ratio are either the recent extensions of Lahore or old settled areas with more land recently added to them. Wards Shahdara, Badami Bagh, Shad Bagh, Moghalpura, Fateh Garh, Kumharpura, Amar Sidhu (excluding the area transferred to Lahore Cantt), Gurumangat (excluding the area transferred to Lahore Cantt)

TABLE II
LAHORE
LAND AND POPULATION RATIO 1968 & 1972

Ward No.	Name of Ward (Union Committee)	Area in % of Total	Population % of Total		*LIP* Ratio	
			1968	1972	1968	1972
I.	Shahdara	6.49	1.97	3.16	1: 0.30	1: 48
2.	Badami Bagh	3.46	2.11	2.28	1: 0.61	1: 65
3.	Wassanpura	0.80	1.93	1.57	1: 2.41	1: 1.90
4.	Shad Bagh	10.31	2.31	3.09	1: 0.22	1: 0.30
5.	Farooq Ganj	0.12	1.71	1.33	1:14.2	1: 1.8
6.	Faiz Bagh	0.12	2.05	1.52	1: 17.10	1: 12.66
7.	Kot Kh. Saeed	0.57	1.94	1.82	1: 3.42	1: 3.19
8.	Tezab Ahata	1.13	2.30	1.86	1: 2.03	1: 1.65
9.	Baghbanpura	0.30	1.48	1.45	1: 4.93	1: 4.83
10.	Moghalpura	2.04	1.46	1.82	1: 0.71	1: 0.89
II.	Ganj	0.68	1.75	1.77	1: 2.53	1: 2.60
12.	Baghbanpura (Southern)	1.01	1.60	1.92	1: 1.60	1: 1.90
13.	Baghbanpura (Northern)	1.56	1.62	1.96	1: 1.04	1: 1.25
14.	Shalamar Town (Daroghawala)	1.68	1.92	2.15	1: 1.14	1: 1.28
15.	Fateh Garh	4.71	2.10	2.03	1: 0.44	1: 0.43
16.	Kumharpura	5.43	2.15	2.95	1: 0.40	1: 0.54
17.	Dharampura	1.18	1.85	1.97	1: 1.61	1: 1.66
18.	Mian Mir Sahib	1.59	1.63	1.78	1: 1.02	1: 1.12
19.	Amar Sidhu (excluding the area transferred to Lahore Cantt).	1.11	0.23	.64	1: 0.21	1: 0.57
20.	Gurumangat (excluding the area transferred to Lahore Cantt)	5.02	1.52	2.70	1.0.30	1: 0 ..54
21.	Gulberg	5.10	1.50	1.67	1: 0.30	1: 0.33
22.	Model Town	5.15	1.60	2.77	1: 0.31	1: 0.53
23.	Muslim Town	7.85	1.52	1.85	1: 0.20	1: 0.23
24.	Pakki Thatti	3.94	1.98	3.05	1: 0.50	1: 0.77
25.	Ichhra	1.20	1.90	2.78	1: 1.60	1: 2.32
26.	Jamia Ashrafia	1.41	1.94	2.28	1: 1.32	1: 1.55

Table I/.-Contd.

Table/I.-Contd.

Ward No.	Name of Ward (Union Committee)	Area in %of Total	Population % of Total		LIP Ratio	
			1968	1972	1968	1972
27.	Samanabad	0.71	1.50	1.65	1: 2.11	1: 2.32
28.	Rifle Range	6.37	2.62	3.23	1:0.41	1: 0.51
29.	Sanda Kalan	2.37	2.20	2.84	1: 0.93	1: 1.19
30.	Rajgarh	0.45	1.70	1.65	1: 3.81	1: 3.66
31.	Krishannagar	0.50	1.76	1.26	1: 3.52	1: 2.52
32.	Mozang	0.25	1.33	1.15	1: 5.32	1: 4.60
33.	High Court	0.25	1.22	0.93	1: 4.90	1: 3.72
34.	Bh. Mozang	0.16	1.22	0.88	1: 7.62	1: 5.50
35.	Civil Lines	2.26	1.16	0.98	1: 0.51	1: 0.42
36.	New Garhi Shahu	1.30	1.35	1.41	1: 1.04	1: 1.08
37.	Garhi Shahu	0.32	1.40	1.27	1: 4.40	1: 3.97
38.	Muhammad Nagar	0.74	1.80	1.56	1: 2.43	1: 2.10
39.	Landa Bazar	0.25	1.95	1.02	1: 7.80	1: 4.08
40.	Islamia College	0.11	1.20	0.78	1: 10.90	1: 7.09
41.	Qila Gujjar Singh	0.30	1.66	1.19	1: 5.53	1: 3.90
42.	Shah Abul Muali	0.17	1.20	0.78	1: 7.06	1: 4.58
43.	Beadon Road	0.22	1.64	1.30	1: 7.45	1: 5.90
44.	Hall Road	0.54	1.55	0.92	1: 2.90	1: 1.70
45.	Gowal Mandi	0.07	1.77	0.95	1: 33.0	1: 13.57
46.	Mayo Hospital	0.24	1.50	1.06	1: 6.45	1: 4.41
47.	Anarkali	0.22	1.42	0.95	1: 6.45	1: 4.31
48.	Sant Nagar	0.68	1.40	1.18	1: 2.06	1: 1.73
49.	Data Sahib	0.90	2.04	1.97	1: 2.30	1: 2.10
50.	Mohni Road	2.16	1.63	1.83	1: 0.75	1: 0.84
51.	Qila Lachhman Singh	2.90	1.98	3.62	1: 0.70	1: 1.24
52.	Bhati Gate	0.13	1.36	1.03	1: 10.50	1: 7.92
53.	Said Mitha	0.10	1.51	1.08	1: 15.10	1: 10.80
54.	Badshahi Mosque	0.36	2.06	1.44	1: 5.72	1: 4.00
55.	Lange Mandi	0.05	1.40	0.83	1: 28.00	1: 16.60
56.	Yakki Gate	0.01	1.60	0.97	1: 160.00	1: 97.00
57.	Akbari Mandi	0.13	1.36	1.03	1: 10.50	1: 7.92
58.	Mochi Gate	0.09	1.40	0.86	1:15.55	1: 9.55
59.	Rang Mahal	0.15	1.50	1.01	1: 10.00	1: 6.73
60.	Lohari Gate	0.07	1.52	1.06	1: 21.71	1:15.14

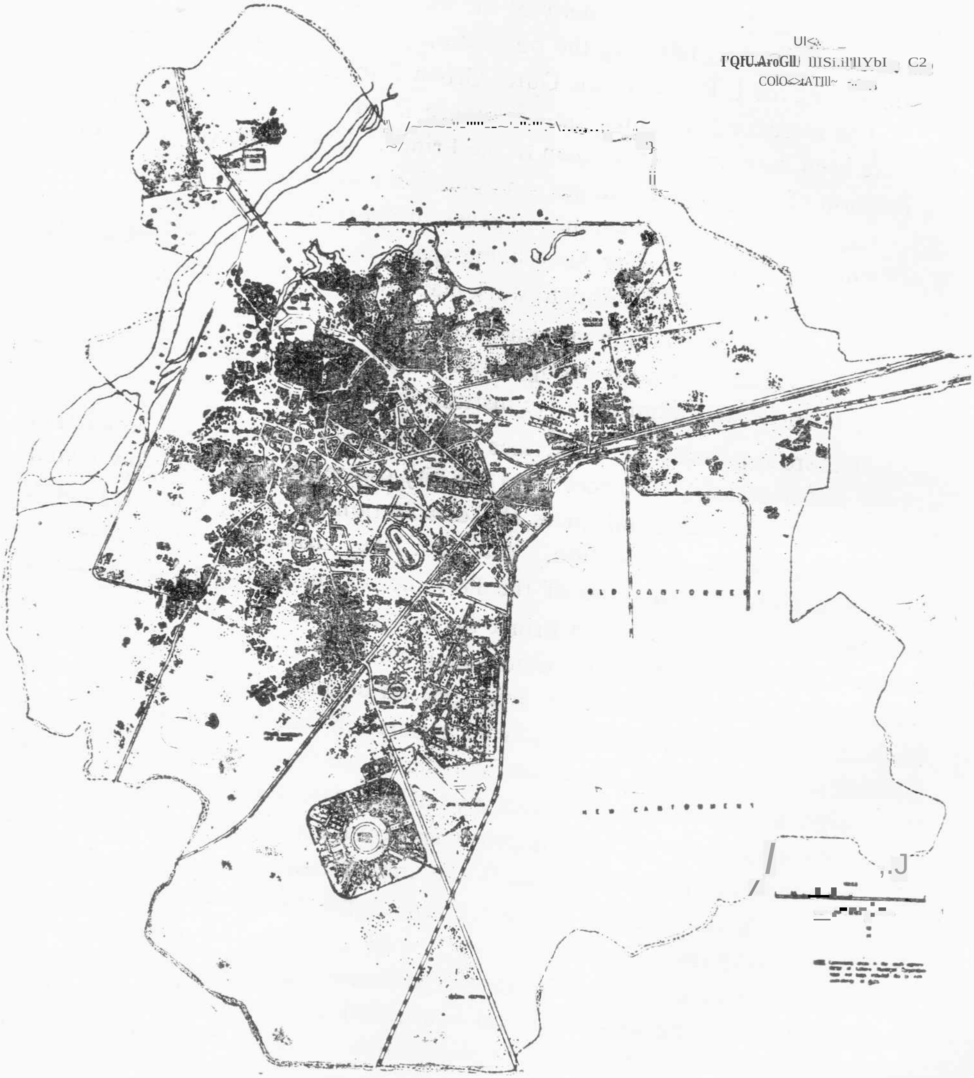


Fig. 5

up between Ferozepur Road and Multan Road. There is no evidence of slackening in the rate of expansion. Continued increases in density still seem likely in the Inner Urban Fringe of Lahore.

However, the available evidence suggests that the process is characterised not so much by random additions as by clustered growth. New settlements are being added in the vicinity of existing ones. Growth is positively being related to density at least up to the level where the exhaustion of the supply of land makes further density increase unlikely as is the case in the inner most parts of the Urban Fringe. Lahore while growing outwards is incorporating in the course of its expansion, older centres which were once separate and independent or semi-independent like Model Town, Ichhra, Nawankot, Rajgarh, Baghbanpura, Moghalpura, Ghari Shahu and Misri Shah. In general however, the city's population growth has set in motion the inevitable process of locational competition which overweighs the fading forces of the past history and is bringing about continuous migration and functional specialization. Thus the trend is that operational location of industry and retail which have recently favoured the selection of fringe areas in many cases rather than the central city locations, has also favoured population distribution.

The generalization that population density declines exponentially from the city centre predicts uniform low densities for the Urban Fringe but this gives a rather lopsided view, fringe areas usually have alternating patches of low and high density, separated by large areas with little existing residential function. Some of such areas lie vacant and in most of them industry or commercial activities are being carried on and therefore the map showing population distribution would show them as having no residential settlement.

As the population is growing it is eating up its agricultural land and instead, industrial, residential and commercial activities are replacing agriculture and associated rural activities. Many small villages in the Fringe such as Kot Lakhpat, Pindi, south of Model Town, and Nasirabad, Amar Sidhu east of Model Town; Sodhiwal, Saidpura, Dholanwal along Multan road and similarly a large number of them to its east as Mahmood Booti, Sultanpura, Kumharpura, Kot Khawaja Saeed, Fatehgarh to mention but a few, are being engulfed by the urban population sprawl as the fringe is continuously adding them to its territory to accommodate the increased need for space.

The distribution of population and the expansion of the city is obviously being accompanied by the expansion of transportation routes in the development of the physical structure of Lahore.

The character of transportation is by all counts the most significant factor influencing the distribution of population. Most other influencing factors exert their effects indirectly through affecting transportation, such as manufacturing plants along radial routes Ferozepur road, Multan Road and the Grand Trunk Road. Growth in the level of manufacturing employment is one of the important growth promoting forces. The factors on which the attractive force of the population distribution is based are low land values, employment opportunity, per capita income, consumer demand, capital formation, investment, and amenity factors. These are but a few of the socio-economic variables which appear relevant in this regard.

Figure No.5 clearly depicts the tendency to axial growth projecting outward from the inner parts and corresponding to the expected effect of settlement. The expansion of population of one area and its encroachment into another is accruing more rapidly along radial routes than elsewhere. The scattering of the population is partly due to accretion at the outer parts of the Urban Fringe in areas away from the major arteries. Such as the Kot Lakhpat Township south of Model Town which has in its expansion covered the Rakh Kot Lakhpat and a few other small villages in its vicinity. Such an outward population expansion is taking place within the framework of existing public amenities where land costs are lower. New facilities such as streets, sewers, water supply and new social uplift in the form of schools etc. is possible. Statistics of the relative growth in the fringe resulting from actual centrifugal migration and that of accumulation of inter-community migrants are not available. It is difficult to estimate how large a proportion of the total metropolitan community population may ultimately be absorbed by the fringe area or to what extent will Lahore loose residents in the centrifugal movement. The process of scatter will perhaps continue for some time into the future till the vacant spaces are filled up. But there are resistances to the spreading phenomenon which accumulate and which may eventually check movement, such as the time, effort, and money spent and daily journeys to places of work, schooling and shopping facilities etc. But whether the gain in living in the Outer Urban Fringe compensate, for expenses involved in satisfying routine requirements cannot be determined until appropriate measures of each variable are available. Many of such costs have been reduced by the growth of population in the urban fringe.

The greatest characteristic of the population of Lahore is its steady and unchecked growth. The limits of distributions and of the expansion will be fixed by time and cost of movement to and from the centre and by expansion from the neighbouring settlements.

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FAMILY PLANNING AND THE HUMAN CONDITIONS IN THE WEST INDIES

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ABSTRACT

In this paper the general population characteristics of the Carribean Islands and outlines of the types of Family Planning Programmes have been studied. Two island nations, Jam:l.ica and Trinidad-Tobago are selected as typical of the region. The working of family planning programmes of both nations is fascinating from the viewpoint of its inception to its fully accepted programme by the government officials and private citizens. The examples of these nations may not be entirely fitting to other developing nations, however, it is author's contention that the specific situation may not be applicable to other developing nations due to their uniqueness but in general the partial success of the above nations can be applied by other developing nations having the same general population difficulties.

The quantity and quality of population are developmental conditions that any striving nation must consider. Underdeveloped nations have certain very general population characteristics, such as: extensive chronic illness and malnutrition; high illiteracy and semi-illiteracy rates; poor technical training and technical sense; and deep rooted social and cultural practices which militate against new farming techniques, specialization, saving, industrialization, efficiency, and family planning. To counteract these conditions all underdeveloped nations have implemented programmes and passed laws aimed at improving public and individual health, general social conditions, technical and managerial skills. However, as true as the above statements are at a world scale, regional population characteristics are observably different. And within any region different political units may respond to their problems in directly similar or opposite ways. The purpose of this paper is to demonstrate this condition in a given region.

We propose to demonstrate the general population characteristics of the Caribbean Islands and outline the types of official programmes utilized to attack the main population problem of the West Indies Region, population quantity. Two island nations, Jamaica and Trinidad-Tobago, will serve as examples. Both exhibit conditions close to standard for this region. To be more accurate examples should be chosen from at least one large and one small island (relative to Caribbean land areas) from each of the islands of English, French, Spanish and Dutch background. However, such a study would be beyond the scope of this paper and, except for information dealing with the larger ex-British islands, resource material is either non-existent or beyond obtaining at present.

Jamaica and Trinidad-Tobago are fairly typical of the legion and can serve as excellent examples of population conditions and family planning programmes in the Caribbean.

GENERAL POPULATION CONDITIONS

Jamaica

Official government figures placed the 1970 Jamaican population at 1,954,000 with a density of approximately 460jsquare mile. This figure assumes the raw area of the nation, 4,411 square miles, however due to the rough terrain of the island only 20% of the land is arable so that population density is really several times the raw figure. In fact, level land is so scarce in upland areas that entire villages hug railway rights of way of road allowances in one row linear patterns.

The block family unit patterns of Jamaica are typical of all the West Indies non-European or non-Asian peoples. In 1970 almost half of the households have female heads and only 26% of the families are officially married. 19% of the unions were classed as common law while an unknown number could be called visiting unions. Also in 1970 there were 400,000 females of child bearing age (15-44 years). For these females, the average age at marriage was 29, while the average age of motherhood was 18; 70% live births were illegitimate. These conditions lead to many obvious social problems, child care nutrition and education being the most serious. Interesting conditions like naming patterns also result. In Jamaica, many people do not use a surname for obvious reasons. Often they take on several names: a very British name reminiscent of plantation days, e.g., Henry Macintyre; a "street name", e.g., Stone Wall Jackson; and since Black Power inceptions, an African name which is unintelligible to a white person.

At this point a word of caution is nece5sary concerning official government statements and statistics in the West Indies. First, amongst the general populace there is a strong distrust for any form of officialdom coupled with an earthy penchant to "make joke". Consequently, one must be cautious when reading results of surveys and census undertakings. Also, most underdeveloped countries tend to gloss over conditions and programme success. West Indians, especially politicians, are extremely proud people. This means one must be doubly cautious when assessing reports from the Calibbean.

The growth of Jamaican populations has been recorded from 1844 (first census) as 377,000 to 1,246,000 in 1944 (a 300% increase) to just over 2 million today.

Population growth rate had been relatively low into the early 1900's. At that time the birth rate was *39/1,000* while the death rate was 23/1,000 and out migration to Britain the U. S. and South America was heavy so that total growth was only 15/1,000. Since then, the death rate has dropped drastically to 7/1,000 (1970) and out migration is almost nil while the birth rate has remained at 39/1,000 (1970). It appears though, since 1970 a decline in the birth rate has appeared.

The age structure of Jamaica's population exhibits the typical pyramid form of underdeveloped nations. In 1960, 52% of total population were under 21, 17% under 4 and 3% over 70. This is, in spite of the fact that infant mortality is still relatively high, 39.4/1,000 (1970). Life expectancy is rising though so the pyramid will widen at the top, e.g., 1972 male life expectancy 63, female 67.

The people of Jamaica are predominantly rural. In 1960 Kingston (population 376,500) contained 23% of the total population while the four other urban centres contained only 4% altogether. There exists a condition of intensive urban in migration process. The rural people are leaving their relatively safe but sparce subsistence farms due to population pressures and/for magnetic lures of urban areas.

These people swell the ranks of the urban unemployed, and literally stand idle in the streets giving rise to all sorts of social and criminal problems; especially near the West Dock area of Kingston.

By race, the 1960 census showed.Jamaica to be typical of the West Indies:

76.3%	African
15.1%	Afro Asians and Europeans
3.1%	Asian Indian
1.2%	Chinese
.8%	European.

Officially, the literacy rate for the nation is 85%. This is a typical underdeveloped nation's misrepresentation. Literacy in Jamaica means at a minimum being able to "read" signs and painfully reproduce one's name. In 1960, 15% of the population over 15 years old had never attended school. 77% had some level of primary schooling (schools vary drastically in facilities, equipment, staff and results). 7% had attended high school, 1% post high school. High priority has been given to improving this situation, so as the older die and the younger gains from improvements the figures will be markedly altered by 1999.

Efforts to expand the economy also are of high priority, but population growth has continued to out strip any improvement. The G. N. P. rose 4%

p~r year from 1958 to 1968; but per capita G. N. P. rose only 2.3% per year ($ 497, U.S., 1968) with only 40 % of the labor force *fully* employed. In 1960, 38 % of the labor force were employed in agriculture (a declining figure), 15 % in industry, 13 % in construction, and 15 % were totally unemployed. Unemployment, partial employment and under employment are obvious results of population growth. This condition is further aggravated as agricultural labor demands decline faster than industrial demand takes up the slack, and increasing numbers of young people are graduating from the 700 new or renovated primary schools and 40 new high schools into an economy that has no demand for their skills, or ways to meet their growing expectations.

Trinidad-Tobago

The population density of Trinidad-Tobago is presently over 556 per square mile. Trinidad is 1863 raw square miles and Tobago 116 square miles, however over] /4 of the total area exhibits very rugged or low swamp conditions so that the population densities must be considerably higher than stated. In 1901 the official population figure stood at 274,000 trebled to 828,000 by 1960, grew to 1,027,000 in 1970, and are expected to reach 1,200,000 by 1980.

In 1967 there were 400,000 females within the reproduction age limits of 15-44 years. Most of these women were involved with men in the same patterns as in Jamaica, 35 % married, 15 % common law, and 2 % visiting unions. The same social problems, especially illegitimacy, plague this nation as in Jamaica and the other Caribbean Islands. However, in Trinidad-Tobago these problems are generally confined to the Negro and Negro-Asians-European mixed (43 % and 16% respectively, of the 1967 population); unlike the general West Indies pattern, a large segment is non Black (36 % Asian Indians, 2 % European, 1% Chinese-I967).

The gwwth pattern of this nation has fluctuated more than most of the islands, a rising rate to 7.3 % existed in the 1860's to 1900's, which dropped to under 1% in the 1911-1912 period, then steadily rose to 2.9% in 1960, then dropped to 2.0% in 1968. The growth from the 1930's to the mid 1960's was strictly natural growth, while the earlier rise in rate was largely due to in movement.

Trinidad-Tobago relected the typical high birth rate/high death rate conditions of an underdeveloped country until only the mid 1920's. From then the death rate began to drop at an increasing rate, e.g., infant mortality 11/],000-1951, 6.7/1,000-1967, due to improvd health and medical conditions. Also, similar to all underdeveloped nations Trinidad-Tobago exhibits the typical population pyramid. In 1967 42 % of the total Dopulation were under 15, 15% were under 4 with only 4 % over 65. By 1970, 42 % were still under 15, while

14% were under 4, indicating a small, but important pattern change may be beginning due to family planning programmes.

Trinidad-Tobago is essentially a rural nation. In 1969, 25% of the population were in Port of Spain (population 100,000-1969) and 6% were in the other 3 major centres. As on the other larger islands movement to the urban areas is strong. But unlike most, this movement is generally along racial lines. Blacks, with a distaste for agricultural labor and feeling a new sense of power since independence are attracted to civil posts and urban jobs in the more colourful city environment.. The Asian Indian family groups, on the other hand, are effectively cut off from many urban positions and have no distaste for living by agricultural endeavors, so they remain in the rural areas, often taking over ex-Negro subsistence and making it commercially productive.

Officially 89% of the population is literate, again this is somewhat exaggerated, but near the truth due mainly to the influence of Hindu and Moslem Schools privately built to meet the strong education demands of the Indian Asians and greater previous public spending on public education again improved education is a prime target.. To date 450 primary (40 since 1961) and 120 high schools (70 since 1961) exist in the nation.

1968 per capita G. N. P. was $ 755 U. S. up from S 425 in 1958. Solely on this criteria Trinidad-Tobago can be classed along with Aruba as the least undeveloped of the undeveloped in the Caribbean. Unfortunately, in 1968 the participation rate of the total labor force was only 62% (86% men, 36% women). The labor force had grown 3% from 1960 to 1968 (368,000) but participation had only grown by 2%. A. 5% emigration, mainly to Britain, reduced the seriousness of the situation; but, this avenue is now closed. Ofthose working 21% are in agriculture (declining) and mining (mainly oil) and 31% in manufacturing and construction mainly spurred by the oil industry. Fortunately, for the total picture, a decline in population growth has recently occurred. But there will be an effective time lag into the late 1970's as the present youth will tontinue to enter the labor market and find few opportunities. This, of course, is not a problem characteristic of only underdeveloped nations.

POPULATION CONTROL PROGRAMMES

Jamaica

The traditional method of population pressure reduction in Jamaica, as in most of the West Indies, has been emigration to Britain, U. S., and South America. This practice peaked in the mid 1950's and rapidly declined, particularly after the 1962 British Immigration Act restricted the flow of colored people to Britain (almost completely stopped today). Fortunately, family planning programmes have been implemented in some islands and are beginning to show signs of moderate success as is the situation in Jamaica.

Family planning in Jamaica was organized originally by a private group, the Jamaica Family Planning League, in 1939. A clinic was opened in Kingston in the same year. This organization enlarged slowly (second clinic opened in 1954) then moved rapidly in the late 1950's and early 1960's; renaming itself the Family Planning League and became a member of the Planned Parenthood Federation. New clinics were opened and problem related studies carried out.

The government had remained completely inactive in relation to this problem until 1956 when it officially approved a 3-year study by the Family Planning League of attitudes toward family planning and a second study of the Jamaican family structure. The study indicated a majority of Jamaican women highly receptive to the idea of family planning, but knew little about it. No government action was taken due to the imagined political ramifications of a population control programme.

When the realities of population pressure exerted sufficient pressures the Roman Catholic Church in Jamaica open a rhythm method clinic in Kingston in 1965. Catholics in Jamaica represent only 10% of the population but are an extremely strong economic-political urban based force who represented the prime fear of political leaders who might have considered a family planning programme. Taking their query, both political parties openly supported control measures and the Ministry of Health established a National Family Planning Programme in 1966.

The legal climate of Jamaica presents no hindrance to population control. There have never been laws restricting manufacture, importation or distribution of contraceptive devices, or information. Abortion is the only exception, except in certain rigidly specified circumstances. Pressures are being applied to liberalize these laws, but the government has remained adamant to date.

As part of the National Family Planning Programme a policy forming and operational body, the Family Planning Board was set up as a separate organ under the Minister of Health. On this board all levels and backgrounds are to be represented. Headquarters are in Kingston and 150 clinics are located about the island (many complete with large electric adviertisement signs). Depending on staff availability and client demand clinics operate from all day, 5i days per week to 4 hours once per month. Each clinic functions on a sessional pattern, with a doctor, 2 nurses or mid wives and a trained interviewer. Response has been good from all parts of the island, e.g., from November 1968 to August 1969,25,830 women were admitted to clinics and for the same period in 1969-70, 40,000 were admitted. A small decline in births has already been noted; 36/1,000 (1969) to 33/1,000 (1971). Optimistic forecasts have altered the projected 1980 population figure downward from 3,500,000 to 2,250,000.

The programme badly lacks trained field workers. To compensate, an education official is assigned to every parish (municiple division) to attempt to disseminate information and deal with questions.

Information and materials for the condom, jelly, foam, inter uteline device (I. U. D.), oral and rhythm methods are all offered. These various methods are discussed with each client at the clinic and each woman chooses a suitable method. All information and material is free, except oral contraceptives which are obtained for a token fee of .01 (J) per month.

All interview information and individual programme progress (or lack of) and or changes are recorded and stored in a central computer bank for the benefit of individual clients and for evaluation of this programme.

Since the government has become active it has restricted the Jamaican Family Planning Association to maintenance of their existing clinics. This private group is still active and successful, especially in their field work approach which encourages new clients and continuation of practices.

Several foreign agencies have provided various forms of aid to both public and private agencies. The most important efforts have come from the United States Agency for International Development (A. I. D.), The Ford Foundation and World Bank. A. I. D. has been the most important agency of the trio, maintaining a consultant role on administration, education, communications and statistics problems and procedures; facilitating material and equipment purchases and movement; and assisting the University of the West Indies in training, research, and evaluation procedures related to population problems and programmes. In conjunction, the Ford Foundation has granted $ 338,000 U. S. to the University to help underwrite the cost of this training and research. Finally, World Bank has lent $ 2 million to Jamaica for population programmes However, most of this money is being spent to build badly needed rural maternity centers and to expand maternity care in Kingston Hospital rather than on Family Planning clinics or personnel training.

The Family Planning Programme is now in its sixth year. Certain features and necessary alternatives have become apparent. . First, over 60 % of the clients choose oral contraceptives and 14 % 1. U. D. as the initial method. An additional 6 % turn to one of these methods after one year as a client. Second, 40 % of the clients were referred to clinics by medical people, 28 % by friends, and only 16 % by field workers. The last two figures demonstrate effectiveness of "word-of-mouth" communications when need is high and the need for more field people. Third, attendance at clinics, acceptance and adherence to contraceptive methods has been rewardingly high, and generally cuts across education, social and economic strata. Of course many families who are better situated obtain knowledge and devices privately, thereby not utilizing the public clinics or being included in official figures. More importantly, a strong effort will have to be made to attract girls below 25 to delay first pregnancies, e.g., in 1969 girls 15 to 25 made up 9.4 % of the clients and 23.6 % of the female population. Finally, stronger field work efforts and more education programmes will have to be carried into the rural communities. In 1969 nearly 40 % of all public clinic clients were in Kingston or its suburb parish, St. Andrew; while, approximately another 40 % were located in towns, especially the larger centers such as Montego Bay and Ocho Rios.

Trinidad-Tobago

The first family planning efforts in Trinidad-Tobago began in 1956 when an American doctor attached to an American oil firms hospital opened a clinic as a public service gesture in response to the need he realized existed. From one man's actions a private organization developed and by 1959 several other clinics had been set up. The basic goal of this group was to provide knowledge of medically approved contraceptive methods and subsidize payments for those who could not afford the purchase price.

The success and growth of this organization fluctuated due to lack of general public support or official recognition, low volunteer funds and Roman Catholic resistance. But the movement did grow. In 1961 the organization took the title of the Trinidad-Tobago Family Planning Association and affiliated with the International Planned Parenthood Federation. By 1965, 3 urban and 2 rural clinics were in continuous operation; each staffed by 2 paid mid wives, one salaried field worker and rotating medical personnel.

Not until the Second Five Year Plan was announced in 1964 did the government officially recognize that a better balance between birth and death rates was primary to any other economic or social development and officially state that steps would be taken to reach a "better balance". Of course a poll had been taken previous which indicated the public would accept such a statement.

Consequently, in 1967 a Population Council was organized under the Minister of Health to co-ordinate all family planning activities and to commence a national programme. The Council has two goals: to lower the birth rate to 20 1,000 by 1977; and to insure the health, social and economic well being of mothers and young children. As in Jamaica, this programme is nationwide and non-coercive. Unlike the Jamaican programme, there is strong co-operation with the previously existing private organizations rather than absorption or restrictions.

By mid 1970, 36 clinics had been established (8 co-operating private clinics). The urban clinics operate three times per week, while the others operate as demand, prevalent fertility, density, and staff avajlabilify necessitat eallow. All contraceptives are provided free. Material and child health is stressed almost to the same extent as family planning. High pliority is given to recent mothers, women with special illnesses, industrial employees and teenagers.

Extension through motivation by education was a strong plank in the 1968-1972 Five Year Plan. Since 1970 information and inducements appear weekly in newspapers and on radio, and bi-weekly on television; spot slides appear before movies; hand bills are printed locally and distributed; field workers continuously conduct village meetings and family visits.

Like Jamaica, Trinidad-Tobago has received technical and material assistance from many foreign sources to attack that nation's population problem. Only the names of the major sources of aid differ. For Trinidad-Tobago, the 3 most important aid sources have been W. H. O., the Swedish Internation Development Agency (S. I. D. A.) and the British Ministry of Overseas Development. W. H. O. supplied expertize for training and organization in Trinidad-Tobago and funds for Trinidadians training in Europe or North America. S. I. D. A. assisted in supply of contraceptives and office equipment. The British Ministry of Overseas Development assisted in both the above ways.

The Population Council has been active for 5 years and certain conditions and results can be noted. First, although I. U. Do's were very popular in the pre-government action era of family planning, oral contraceptives were first choice for 73% of the clients in 1969, while I. U. Do's were first choice for only 7%. Second, Trinidad- Tobago's comparatively better level of income and education, by Caribbean standards, made possible the utilization of field workers, mass education through communication media and rapid expansion of clinics and personnel, with predictable results, e.g., after the first 2 years of public clinic operation 15% of the women of child-bearing age (15-44) had attended a clinic. This was before the mass media barrage had been put into "high gear" Also, the birth rate has dropped, e.g., 39/1,000 (1946) to 29/1,000 (1969). It would seem that the need was there and that the government has finally moved to meet it. Mass communications have now informed the public that the services are available and are convincing people to utilize them. Pushing clinics and utilization into the most culturally deprived rural areas of the North East and South West extremities seems to be the last large project necessary to put Trinidad-Tobago on the way to effective population quantity control.

Conclusions

To be truly accurate, an extensive study of each island in the Caribbean would be necessary, but it is reasonable to generalize that, in the West Indies, population quantity is the primary obstacle to better social-economic conditions. This is true of many underdeveloped countries; however, the people of the Caribbean seem to realize this basic problem and desire to practice family planning. This is not true for many other regions. Once knowledge and material are made readily available the people quickly demonstrate capability of consistent, effective utilization. Again this is not the case in many undeveloped regions. This is, of course, a generalization.

It is significant that, for both sample islands, family planning began as a private effort, entered into by government only after independence and only after the political men felt secure in publicly supporting family planning programmes. However, once such planning became official and foreign aid obtained, programmes developed rapidly and are now enjoying reasonable success. This is true of other islands as well, e.g., Barbados, but not for all, e.g., Haiti.

From readings, interviews, and actual observation, it could be said that the West Indies will be successful in their attack on the primary problem of rapid population increases. The question is, will they succeed in solving the other problems only hinted at in this paper and the greater multitude of other serious geographic, economic, social and political problems which plague this region of rich potential..

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GEOMORPHOLOGY OF PARTS OF NORTHERN THAL DESERT

ANIS AHMAD ABBASI

Purpose of Investigation

The objective of the investigation of parts of Northern ThaI desert was to collect information regarding the geological characteristics of the alluvium and the surfacial sand deposits overlying it. The data was initially meant for the planning of the proposed ThaI Reservoir with storage capacity of 4 million acre feet. Information concerning the nature and characteristics of soils and underlying sediments, their horizontal and vertical extent were collected through extensive test drilling, field mapping, pitting and trenching. The field and laboratory data was analysed. The following geomorphic study is based on the above mentioned data.

Location and Extent of Area

The study area lies between lat. 31°30' Nand Lat 32°0' N, longitude 71°42' E and 72°10' E in ThaI Doab. Chashma Jhelum link canal forms its northern boundary. (Fig 1.) Its eastern boundary coincides with the Jhelum river flood plains. The western boundary lies 20 miles to the west and is parallel to the eastern boundary. The total area in which field work was carried out is 550 sq. miles. Fig. 1 shows the location and extent of the area studied.

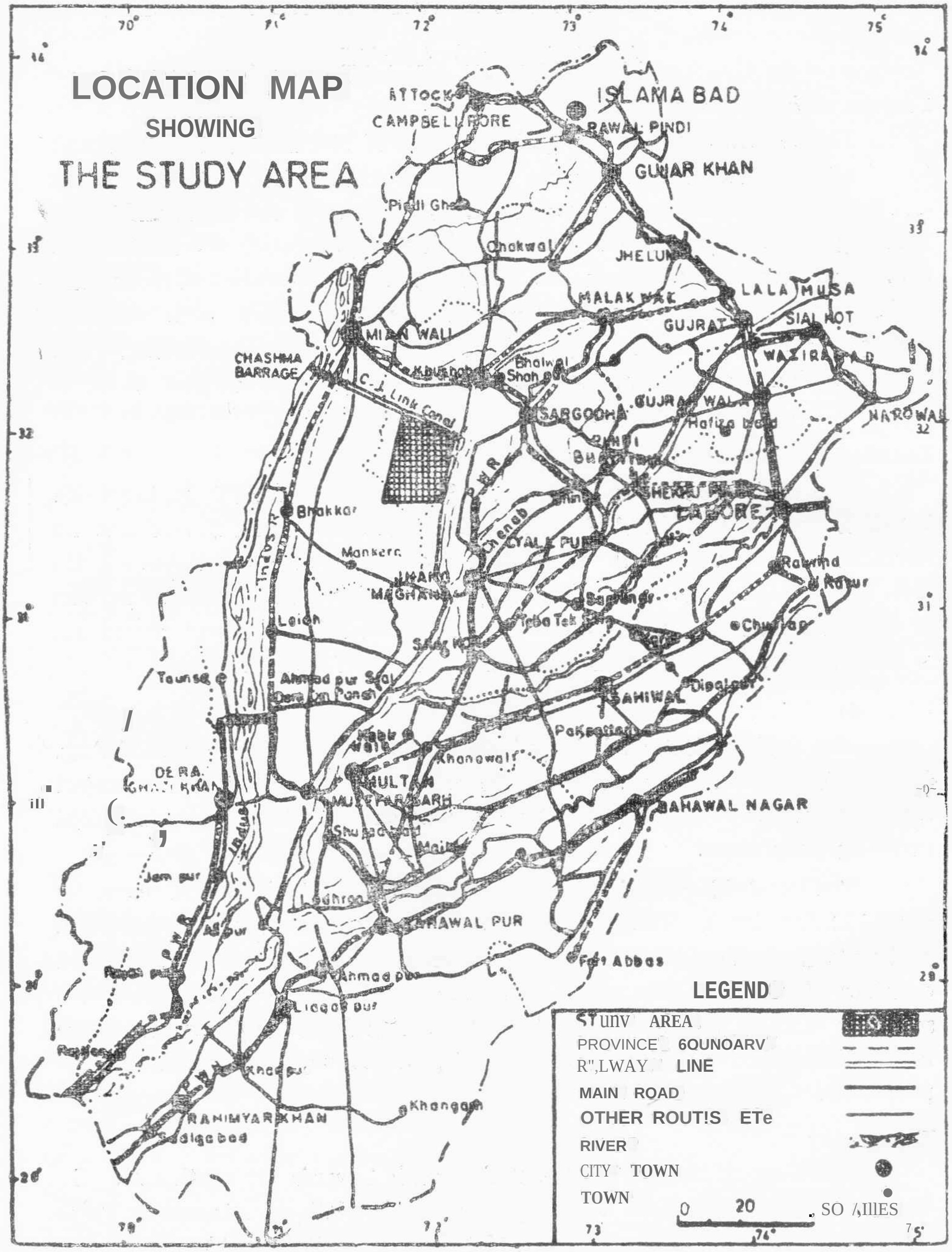
Methods of Investigations

The field work for this investigation was done during the period Aug. 1973 to April 1974. In the initial stage reconnaissance surveys in the project area were carried out, based on this surveys, an extensive test drilling, and field mapping programme was prepared.

The test drilling consisted of auger holes upto 20 ft. depth and deep holes upto 100 feet depth. The plan for the pattern of holes was prepared on a grid system. In the first phase of investigation, 20 [1. auger holes having field densities of one auger hole per 1.2 sq. miles were maintained. Representative sediment samples at the surface of the dunes and from the auger holes were collected for laboratory determination of physical, engineering and chemical properties.

Topography

The slope of the land in the study area is towards the south east. On the average, the slope of the alluvial plain which is relatively flat; and on which sand dunes are superimposed is about 1t to 2 feet per mile (Fig. 2.) Unevenness of the surface is due to the transported eolian sand deposits which have created


LOCATION MAP
SHOWING
THE STUDY AREA
ISLAMA BAD
ATTOCK
CAMPBELLPORE
RAWAL PINDI
GUJAR KHAN
Pindi Gheb
Chakwal
JHELUM
LALA MUSA
MALAKWAL
GUJRAT
SIALKOT
MIANWALI
CHASHMA BARRAGE
Khushab
Bhalwal
Shah pur
C. J. Link Canal
WAZIRABAD
SARGODHA
GUJRANWALA
Hafizabad
NAROWAL
Bhakkar
Indus R.
Chenab
LAHORE
Mankera
LYALLPUR
Raiwind
Kasur
JHANG MAGHIANA
Samundri
Toba Tek Singh
Chunian
Leiah
Shorkot
Taunsa
Ahmad pur Sial
Dera Din Panah
SAHIWAL
Dipalpur
Pakpattan
Kabirwala
Khanewal
DERA GHAZI KHAN
MULTAN
MUZAFFARGARH
BAHAWAL NAGAR
Shujabad
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Jam pur
Lodhran
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Fig. 1.

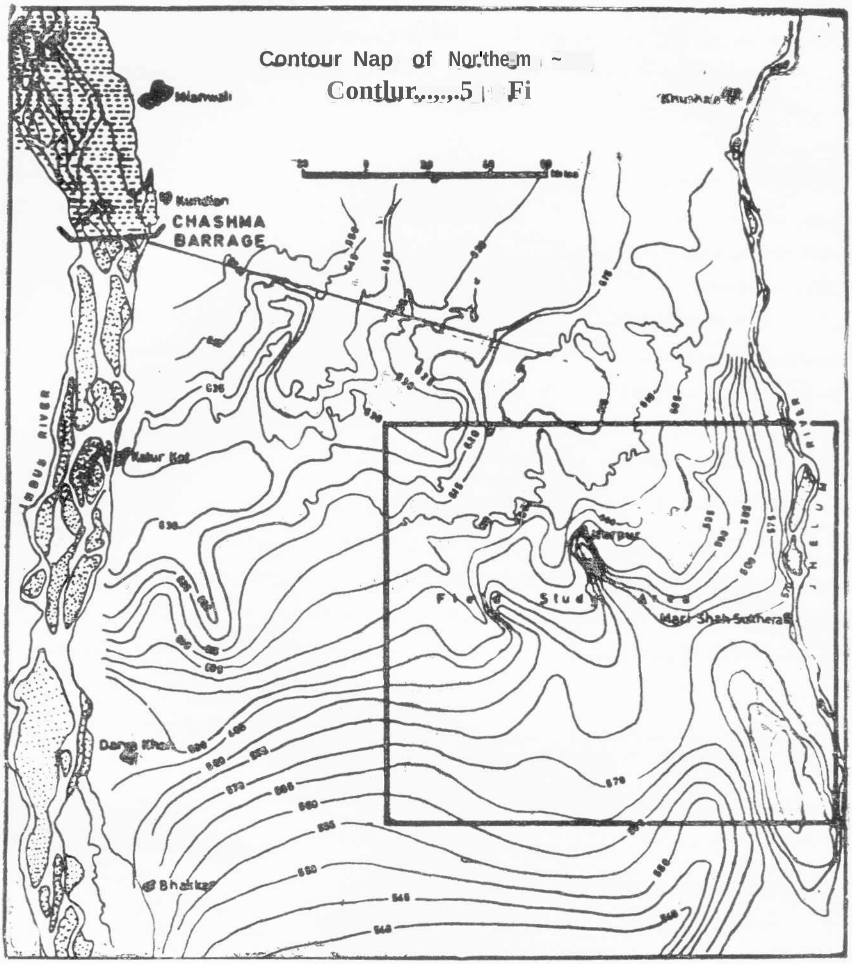


Fig. 2

the present configuration in the form of sand undulations, sandy ridges, and sand sheets. Local relief of the eolian features varies from place to place. The sand ridges and the dunes may rise 10 to 20 feet, and in some cases to as much as 30 ft, above natural surface level of the alluvial plain. Another feature of the unevenness of the surface is due to the old deserted channels of the rivers which are 1-2 miles wide, 5-10 feet deep, in places covered by patches of sand; elsewhere completely exposed. To the east of the study area a few miles away is the active flood plain of river Jhelum which lies 40-50 feet below the dune surface of ThaI Doab. The land surface of the study area is located on the Bar (terrace) land and separated by a vertical escarpment, varying in height, which runs all along the Bar upland. The sharp boundary between the Bar upland

and the active flood plain of river Jhelum is occasionally inerrupted by old local drainage channels, whose entry into the river has destroyed the sharp break in topography and replaced it by gradually precipitating slopes towards the master stream i.e. River Jhelum.

Drainage

Due to the local variations in topography the drainage of the area is rather complex. About 80% of the area has inland drainage system. The rainwater falling on the eolian features collects in the interdune depressions. Due to compactness of the silty sandy plain on which the depression are generally located, the infiltration is low and runoff water stays in these depressions till it is evaporated. However, during exceptionally heavy downpours water finds its way through the local abandoned channels which run to the south of the area and drain into river Jhelum.

The master stream Jhelum lies about 3-4 miles east of the periphery of the area. The river is subjected to extreme fluctuations of flow; the mean monthly discharge during the summers is 15-25 times that of winter months. However, after the flood season an additional supply of 20,000 cusecs is poured into the river through Chashma-Jhelum Link Canal, the confluence of which with the Jhelum river is located just in the N. E. Corner of the area.

In the north, the natural drainage of the Doab is interrupted by the high banks of the C-J. Link which runs parallel to the northern periphery of the area and carries intermittently a discharge of about 21,000 cusecs during the off flood season.

Geological Misconceptions

Those who have not visited the ThaI Desert have a common fallacy about the land that it has little or no vegetation, that it is always hot, and consists of drifting sand and sand dunes miles after miles. The most paradoxical misconception, apparently logical, is that the winds have been responsible for the creation of the entire Thailand forms.

Field work has revealed that vegetation in the form of shrubs, grasses and trees is present and widely distributed throughout, although it is in scantier form as compared with the surrounding irrigated areas. Some species of vegetation (discussed elsewhere) love the desert environment and thrive well here. Since the geological work was carried out throughout the year 8-10 hours a day, experience shows that the desert is not always hot. During the day time the air temperature may rise as much as 118°F (and the temperature on sand surface may rise as high as 140"F), but at night it falls many degrees lower than that during day time, During windy periods, sand is, everywhere, on the ground and in the air. The sand storms forbidding one to move out gives the feeling that perhaps the wind is mainly responsible for evolving the Thal desert landforms. As a matter of fact water has also played an important role in the creation of land forms as an important geomorphic agent, by removing the fines from dunes and depositing it in interdunal space of shifting sand thus creating a hard pan of fine sandy material throughout.

Environment

Major characteristics of the environment of the Thal desert are:-

The rainfall for all the seasons is 10-12 inches. Irregularity of rainfall is typical. Average rainfall values have little significance. One torrential rain may equal or exceed the so called mean annual value, which is simply an average arrived at from a number of irregular and variable amounts of precipitation. Records of heavy precipitation for 1 hour, 5 hours, 10 hours or 24 hours are comparable with those of humid regions.

Evaporation is very high generally 10-20 times the annual precipitation. Cloud cover is very low approximately 80% of the time the sky remains clear. Relative humidity ranges between 10-20%.

Generally speaking two major Geomorphic processes fluvial and eolian have been operating in the region. Dunes are superimposed on the fluvial flood plain. The overlying materials are of completely different origin, and can be identified on aerial photographs. On the ground exposed, the underlying formations have developed distinct land surface from, which is flat, hard, and almost imperemeable.

Geomophology

(i) *Photo-Geomorphological Analysis.*- The Colombo Plan Air Photographs, along with Multiplex diapositives and, Mosaics (Semi-controlled) at contact prints scale of 1 : 40,000, covering an area equivalent to 1: 50,000 scale topographical sheets of Survey of Pakistan with the same numbering system, were used for mapping.

Interpretation

Geomorphological analytical methods and techniques used in the study of the soils and land forms of the area showed relationship between microgeomorphological features and the photographic tones in the area.

Darker tones seen on the photographs represented the existence of fine grained material. In areas of moisture the tones were still more darker.

Brighter tones were seen in the areas of slight elevation which were composed of coarse grained material and were generally speaking well drained.

The ancient abandoned channels were identified taking into consideration the micro-relief features, tones and the Photographic texture.

Majority of areas with slight elevation, were generally composed of relatively coarser material than the adjacent lower elevation whereas fine grained soils were identified in the inter dunes areas.

In addition to the above characteristics several other field criterion were used in the mapping and delineating the major land form units. The geomorphological environments, geomorphic agents and surface slopes of the area were also taken into consideration.

(ii) Based on Airphoto interpretation the area has been divided into 4 geomorphic units which have their own typical land surface forms and mode of formation.

Active Flood Plains

This land form occurs in the east of the area in the flood plain of river Jhelum. It is generally 40 to 50 feet below the natural surface level of the Thai Doab. The active flood plain of Jhelum river in the vicinity of the study area is as much as 3 miles wide. Natural levees, back water swamps, sand bars and meander scars are prominent features within the active flood plain. During low discharge stages large stretches of dry riverain sand is visible in the active flood plain.

Abandoned Flood Plains

Abnadoned flood plains appear a few feet higher on the air photographs from the adjoining active flood plain and are confined to a few location in the north. The material in these plains was deposited by the high flood flows after the river Jhelum abandoned its old course. Gradually, subsequent sedimentation has produced a fairly level plain in this area. The former river pattern, have not been completely oblitrated and are clearly visible on air photos due to their distinct tone and texture. Even today during exceptionally high floods these areas are inundated and fine sediments are deposited on its surface.

The Bar Upland

Separated from the recent flood plain by a vertical escarpment is the central upland surface of the ThaI Doab designated by local people as "BAR" which rises 40-50 feet high from the adjoining flood plain and runs almost parallel to Jhelum river. In places the vertical face has been obliterated by gully erosion and replaced by gently undulating topography which merges into the recent flood plains of Jhelum. Field studies of the soils and geological cross sectio'l shows that the material of the 'Bar' upland, most probably belongs to late pleistocene age. The soils are generally homogenized and have a distinct kanker zone. The original surface of the 'Bar' upland lying in the area shows sign of reworking by fluvial agencies and is traversed by broad elongated depressions which have been designated in the present study as Nurpur, Jamali and Ainu Channels.

Sand Forms

Almost the entire surface of the study area is covered by sand, the forms of sand dunes are related to wind directions and speed. The sand forms have acquired various shapes and sizes. In some area dunes are in the form of ridges which are aligned parallel to the prevailing strong winds and transverse features appear to be aligned at right angles to the weak winds. The dominant wind directions of the area are shown in wind rose (Fig. 3.) The theories of dune formation are many and complex, they have not been discussed there. However, individual sand forms of the region have been described in detail.

Channels (Abandoned and Covered)

The 'Bar' upland surface is traversed by at least well marked three channels which run longitudinally through the area. They represent actually broad elongated depressions generally called by the local people as 'Patti' Land. A thorough geological and soil investigation of these channels has revealed that they are probably a little younger than the material of the 'Bar' upland. Topographically it is not possible for either the Indus or Jhelum flood water to reach these channels. However, due to their low position these depressions collect local run off and during exceptionally high rainfall some water may actually be seen flowing in some parts of these channels.

Severely Eroded Land

This unit of land form is found at the contact of the 'Bar' upland and the terrace escarpment which rises 40 to 50 feet from the flood plain of the river Jhelum. It is located at intermittent spacing between Tetri to Bullo. Due to severe soil erosion the original surface has been obliterated. On account of sudden breaks in topography water has cut deep into the soil and gullies are most conspicuous in the land form.

SOURCES OF SAND

Flanked by the Indus and the Jhelum rivers in the west and east respectively and the Salt Range in the north, the Doab is geologically different from the Bari, Rechna and Chaj Doabs of the Indus plain. Wind blown sand fine eolian material express the topography of the area, while fluvial deposits generally underlie the surfacial eolian material. Below the

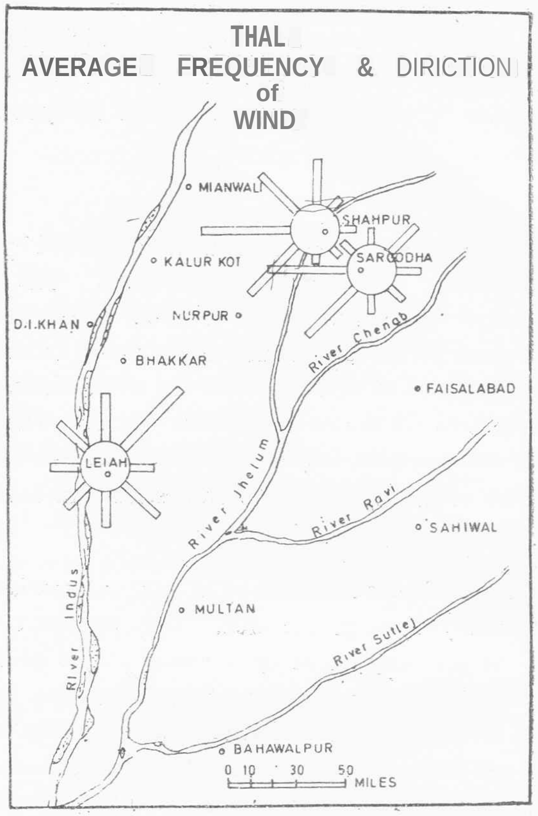


Fig. 3.

surfacial blanket of sand, and dune material lies a layer of fine textured alluvial deposit which can be seen exposed in irregularly shaped interdune spaces as a table flat, devoid of any topographic expressions. Their shape and area is variable from place to place.

The sand in ThaI, geologically speaking seems to have been formed over the last few thousand years and belongs to most recent stage in the geological time scale. It is possible that the sands of ThaI may have been originally deposited as alluvium by the Indus and Jhelum rivers later due to shifting of the courses of these rivers, the alluvial deposits may have been reworked by wind action forming the present desert dune and sandy topography. From the field evidences, it appears that the region has remained under arid conditions for over a couple of thousand years; During this time active flood plains of river Indus and Jhelum may have been a large source of sand. The aridity along with high frequency of dust storms in the region transported the sand from the river bed\1to the upland areas. Gastropods which live on the land surface in the area under more humid conditions and subsequently due to climatic accidents disappeared or became extinct, were buried in the soil, lie exposed on the surface and indicate that the top soil has been and is under the process of erosion. Since the material of the topsoil found in patches in interdune areas is silty sand and clayey sand and the material beneath being fine to medium sand, it may have been the source of sand in the region. Other sources of sand, if we try to interpret the existing pattern of sand assemblages in Pakistan, could be the Thar and Cholistan Deserts. Gori in his work on desertification in Punjab has partly assigned the source of sand in Thal area to be the deserts of Thar and Cholistan.

It seems that in all probability several agencies concomitantly contributed sand in varying degree in different parts of Thal.

Characteristics of Aeolian Sand

The examination of sand collected from different sides of the sand dunes show that the grain size of the material differs. The sand on the windward sides are coarser, than those on the leeward sides. This is due to the fact that the lighter and smaller particles have been blown away and the larger and heavier left. The mean grain size from the main body of the dunes lies between 0.125 and 0.6 mm approximately and the grain dimension of over 90 per cent material lies between these figures (Fig. 4). The average grain size of the sand on the leeward side lies between 1·6 and 1·2 mm. In places from where the dunes are shifted the lag gravel or

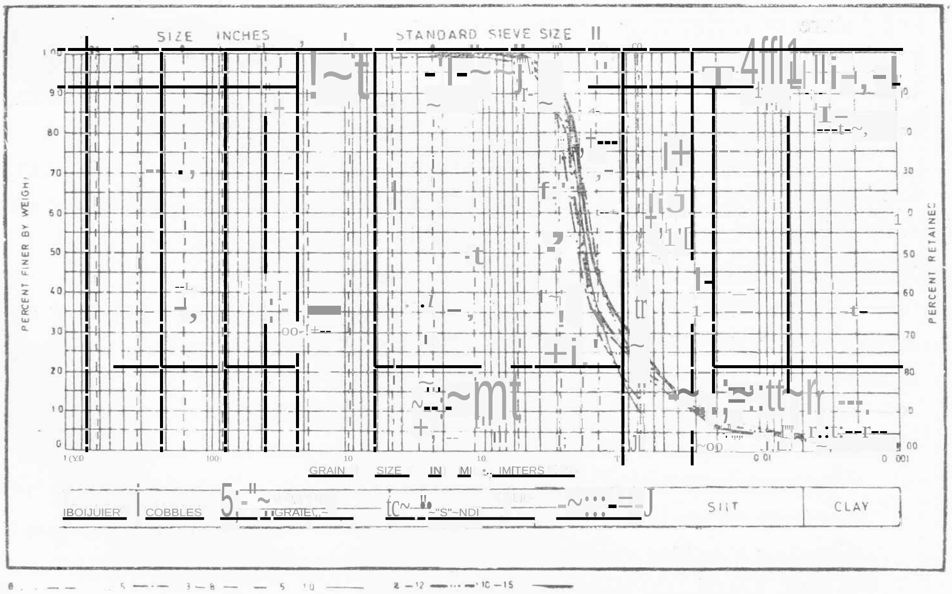


Fig. 4.

kankers are seen lying on the flat surface. The kanker have dimension between I 8 and 6 mm. At places the kankers cover the surface of inter dunes areas from which sand and dust have been removed. The sand deposited on opposite side of the dune vary in grain size and differ in the same way as the sand deposited in the depressions between the dunes.

The Sphericity of Sand Grain

As the sand grain rolling on the dunes and suspended in the air strike each other, the grain acquire a frosted or ground glass surface. Many samples of sand from dunes examined under microscope show little rounded frosted surfaces and are mostly angular or subangular in nature.

Structure of Sand Dunes

In dune areas the sand moves by traction. The movement of sand observed during windy periods indicates that the sand moves up the windward side and rolls down the leeward side. Under such circumstances crosslamination is developed on the leeward side. The material of each lamination represents the deposit made by wind of certain velocity and differs from the material of laminations above and below in dimensions of grain, but not in composition. The laminations develop slopes, which are parallel to the angle of repose of the sand dunes. Several measurements made in the dune indicate that the angle of repose of dunes in the area ranges from 32<l to 33°. The leeward slopes of dunes range from 5° to 13° on the average.

The <ii1alysis of meteorological data indicates that the winds in the region are variable. The wind currents blowing on the dune surfaces, due to undulating nature of topography are highly variable in direction and velocity. This produces truncation in laminations and variations in degree and direction of the angle of inclination. The plains of truncation are therefore, not horizontal and parallel and generally acquire wedge shaped cross section.

It can be generally summarised that the sand in the dunes and rolling sand planes are comparatively well sorted and sand gain size particles are not well rounded and are minutely pitted and frosted.

Surface Expression of Sand Forms

Since the wind direction and velocity in the region is variable and the region is not devoid of vegetation, eolian sand tends to accumulate in the region wherever the following conditions are prevalent:

Wherever there is an ample sand source upwind from the site of accumulation.

Wherever obstacles in the way of the prevailing winds are present.

Wherever cultural features such as villages, wells, roads, canals are present.

Wherever a sudden change in topography takes place e.g. near escarpment or near abandoned river channels.

Several sand forms associated with the above mentioned factors are found in the regions. They are:-

Sand veneers.
Sand drifts.
Sand undulations.
Knob dunes.
Longitudinality NW-SE aligned sandy ridges.
Wave and Barchan like dunes.

Sand Veneer Deposits

Generally smooth and sand covered surfaces are not found as individual land forms. But are generally associated with other surfaces. The area just south of the Chashma Jhelum Link Canal in patches has this form of land. In the covered channel areas around Ainu and near Tetri this form is prevalent only in scattered patches. The south of Chashma-Jhelum Link Canal the Veneer is in irregular mantel form. The sands are coarse and patchy. For the most part (Fig. 5) the Veneer is not thick. Small knobs of comparatively finer sand accumulate at the lee of sparse *Harmal, Beri* or *Sakkanda* bushes. As the density of vegetation increases further south the veneer culminates into the knob dune fields.

Sand Drifts

The escapment seen from the river side appears highly undulating and thickly covered with sand deposits. The association of the escarpment dunes relative to the prevailing wind is almost the same as that of a migrating dune. Most of the sand load during a high speed wind is carried forward to the rim of the escarpment in the east. Due to sudden fall in the ground a wind shadow is created which makes the sand grains fall below the edge of the escarpment where they settle. Repeated process of accumulating generates a steeply inclined lee drift, which at times and in places reaches the angle of repose. Occasionally the sand accumulating also results into sand slide, which during the period of active channel of the river Jhelum near the escarpment is washed away. In areas such as south of Leghari village where the escarpment is subdued, the drifting sand has progressively advanced in the adjoining flood plain. Its further advancement in the flood plain is controlled by the high water table and irrigation in the area. The size of the drift sand dunes varies from place to place along the escarpment. In the vicinity of active channel it is washed away. Whereas in other places it is controlled by the limit of Sailaba cultivation.

Sand Undulations

Travelling in the area throughout shows that the entire surface of the area with the exceptions of the exposed channel remnants is covered with sand.

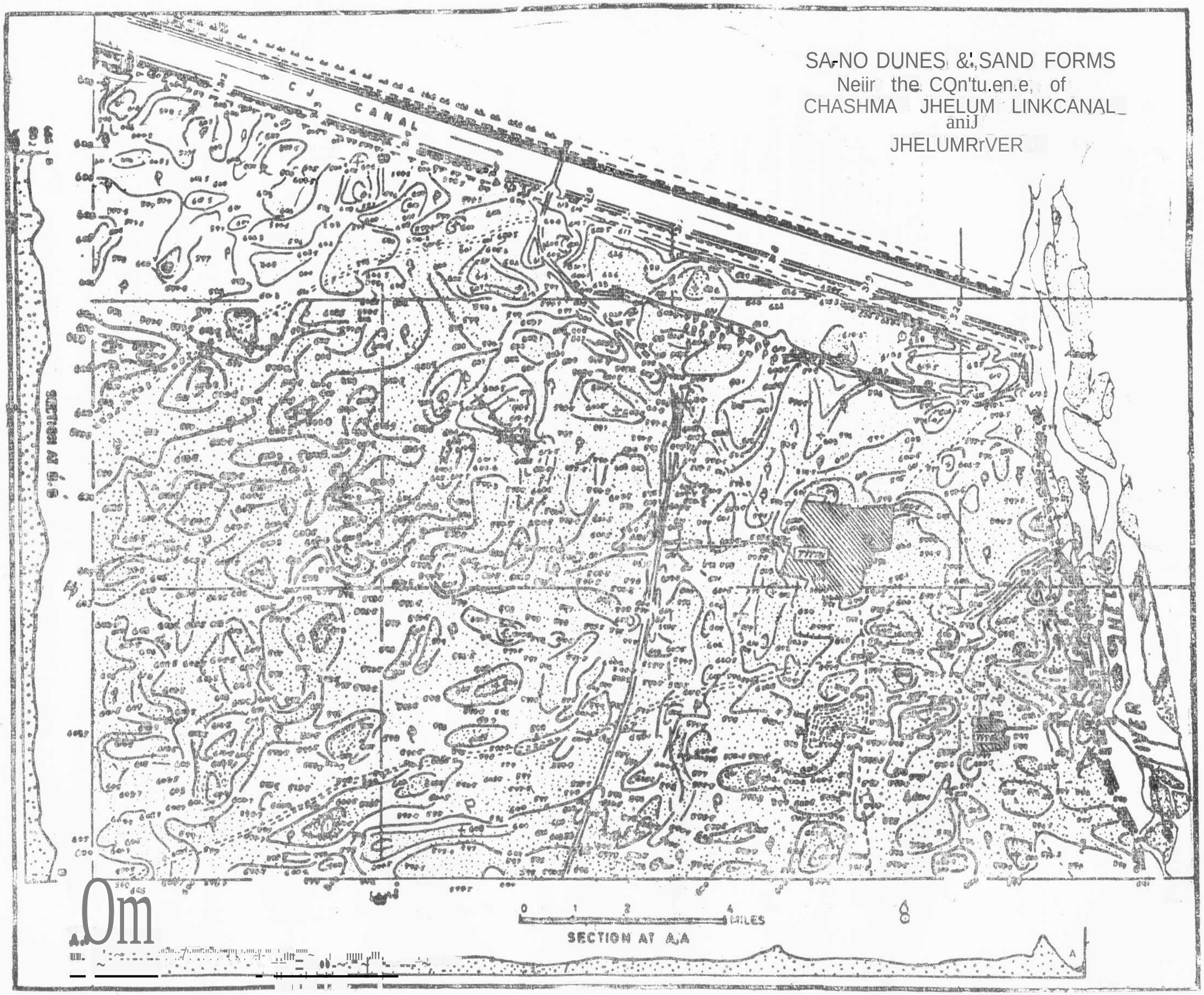

SAND DUNES & SAND FORMS
Near the Confluence of
CHASHMA JHELUM LINK CANAL
and
JHELUM RIVER
C J CANAL
SECTION AT B.B
0 1 2 3 4 MILES
SECTION AT A.A
A

Fig. 5.

This fact becomes clear when one moves from Nurpur area into the central parts of the desert. On this sandy cover, undulations rise in varied shapes some are modified barchan type in shape, some are oval, others are elongated in the direction of the wind. Morphologically their length is generally three to four times the width, and in height from 5 to 25 feet. Some of the undulations measured on the aerial photographs and topographical maps are 200 to 300 feet long and 50 to 80 feet wide. The orientation of the undulations is aligned generally N NE to SSW depending upon the local topographical conditions there may be some deviations in the general alignment, but the over all orientation remains the same. On the south western side of the study area the undulations have developed best. Perhaps the conditions which shape the Barchan type of dunes, with some modifications in wind velocity directions, vegetation cover etc. may have formed the sand undulations in the region.

Barchan Dunes

Barchan type of dunes develop in the areas which are devoid of vegetation, Bangnold regards Barchans as "true dunes". Barchan or crescentic dunes are generally not present in the area. A small part of the exposed channel area to the south of Nurpur is occupied by Barchan dunes. They are generally associated with cultivated areas in so called 'Patti' land.

Ridgy Sand

Longitudinal instriped sand ridges form as stream lined topography which is characteristic of larger part of the area. Their alignment is generally from NE-SW to NNE-SSW which is the predominant wind direction in the area as per Fig. 3. On the aerial Photograph the entire area appears to be spotted with shrubs and vegetation growth. The interdune space is generally devoid of sand and is rich in soil moisture. It is generally utilized for 'Barani' cultivation. The inter ridge or interdune areas have fine silty material which is washed down by running water. During the rainy season pools of standing water can be seen in some interdune areas with comparatively large catchments. After few days is water evaporated leaving behind a thick film of clay and silt about 1-2 mm thick in the central part of the depressions. Mud cracks, varied in hexagonal and other shapes 2 to 8' in width were also seen. These mud cracks and fresh film of fine material deposited in the central part of the interdune areas are indications of washing of fines from the dunes. As the dunes shift new parts are exposed, where fine material deposition and the formation of hard crust of impermeable material continues. The angle of repose in most ot these slip faces is 32' to 33°. The ridge sandy hills are not continuous but they form inter connecting ridges joined by undulations of sand. The ridges joining each other may run for several miles. The height varies from place to place.

average being 15 to 25 feet. The interdune spacing is generally almost equal to the width of the ridges. (Fig. 6). The slip face of the dunes is devoid of vegetation however, the wind ward slopes have good growth of shrubs. Occasionally 'Kikar' 'beri' trees can also be seen.

From the point of view of stability two types of sand dunes are generally encountered in the Area. Fixed sand dunes and the unconsolidated sand dunes. In addition to that there are several other minor variations in each type which merit further subclassification.

Fixed Dunes

The large dunes in the south western area are generally fixed and on excavations show decayed plant roots and scattered pieces of wood buried in them. The carbonate contents in fixed dunes are also high and they also have on top of them some scattered vegetation, which seems to be one of the major factors in binding the sandy material together (Fig. 7).

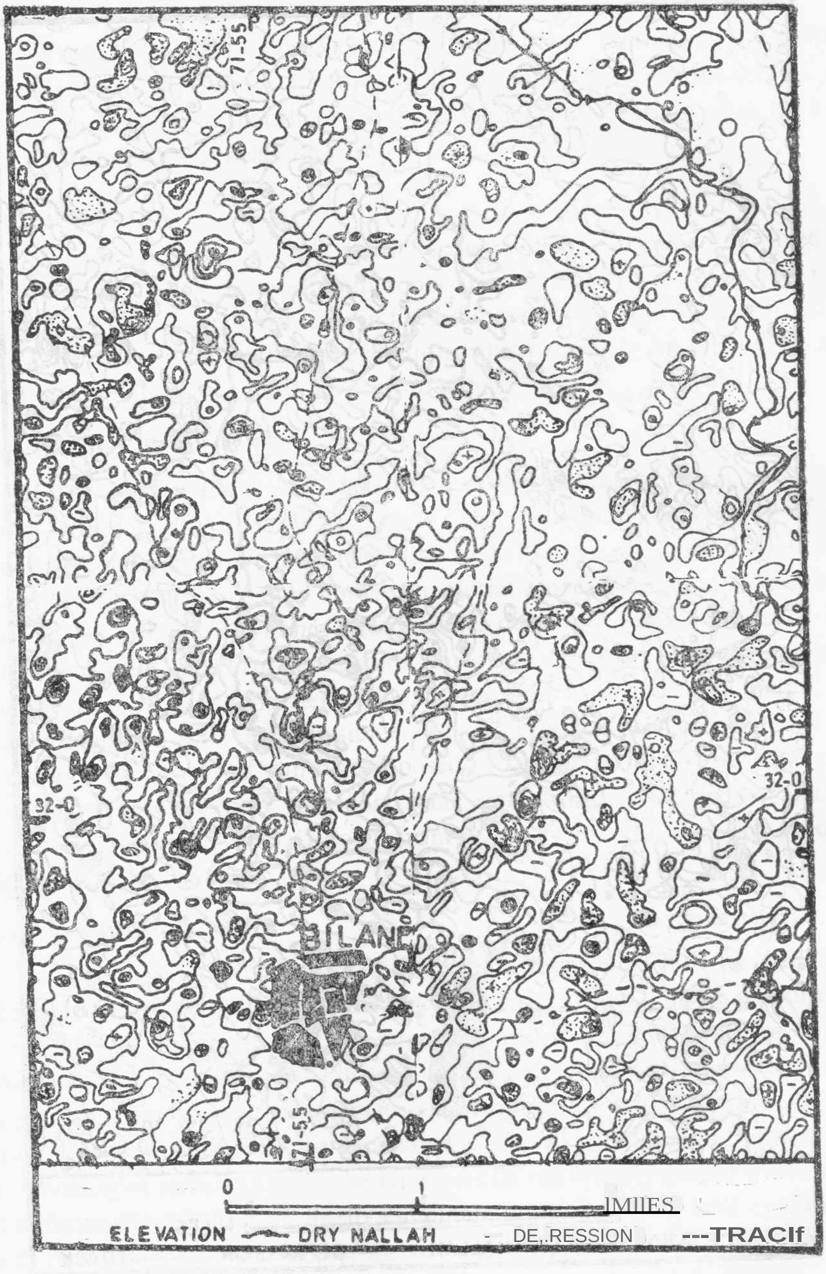
Inter-dune Areas

The wind charged with sand has maximum abrasive power about 6"-9" above the ground. Above that height, depending upon the velocity of wind, the sandy material is not lifted beyond few feet above the ground. Maximum quantity of coarse and sandy abrasive material moves parallel to the surface of dunes. On crossing the dunes strong eddies develop which remove sand in the inter dune areas and form depressions which are somewhat semi-circular to oval and of various other shapes depending upon the dunes surrounding them. Since from the surface of these depressions sandy material has been eroded the residual material is either a hard pan or composed of kankers or coarse material striven throughout.. Winds may transport some sand from the blowouts, and, later on in this area, fines washed down from dunes are deposited. The process of sedimentation continues.

Geological History

The physiographic history of this region truly begins with the uplift during the late tertiary period, when the Indogangetic trough or synclinorum was formed with the uplift of Himalayas. Wadia dates it to the second mid-Miocene and the 3rd post-Pliocene phase of the Himalayan elevation. The depression was subjected to vigorous sedimentation and slow subsidence of crust beneath. Gradually the depression was filled with alluvium brought down by Himalayan streams and in the later part of the tertiary period shallow water conditions prevailed which finally culminated into terrestrial land environments and the deposition of meandering streams have been depositing enormous amounts of sand, silt and clay derived from the ever-rising Himalayas.

Fig. 6,


71-55
32-0
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BILAND
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MILES
ELEVATION
DRY NALLAH
DEPRESSION
TRACK

Fig. 7.

During the pleistocene Ice age this area was not directly under the influence of glacial ice, however, the impact of Glaciations in the catchment areas of the streams reflected on the physiography and sedimentation of the region. Since pleistocene times (10^6 years ago) each glacial and interglacial cycle may have resulted in the modification of drainage, erosion, sedimentation, soil formation and in flora and fauna of this region. The widespread climatic changes during the pleistocene resulted in fluctuations in the sea level, and thus also brought significant changes in the drainage system and in the sedimentary history of the area. The silty terrace cover which extends eastwards of the area having thickness of about 40 feet along Jhelum bank was formed during the last glacial, when the permanently frozen ground of the Himalayan foot-hills melted. The melted water brought with it enormous quantities of loose, silty, sandy alluvium and deposited it in the region.

About 100,000 years ago (early Holocene) widespread climatic changes produced warmer and more humid climate than the present which resulted in luxurious vegetation in the Himalayas and their foot-hills. Abundance of vegetation protected soil and sediment cover. The river flow was higher, more constant and with less sediments. The sea level also rose more than 50 meters to the present level. The profile of equilibrium also changed and the rivers gradients became more sharp. At this stage the rivers started down-cutting and removing the old sediments along their courses and gradually formed cliff faced river terraces between each pair of rivers. The depth of dissection in this part was of the order of 40 to 50 feet.

At this stage the rivers somewhat acquired their lost equilibrium and thus formed the present river plain. As the time passed, the climate changed gradually and by the middle and later part of Holocene, the climate acquired the characteristics of the present days. The rainfall and humidity diminished, the vegetation cover became scanty, the intensity of erosion increased and the runoff in rivers became more seasonal..

During the early Holocene period the Indus kept its westerning tendency, gradually leaving behind its remnant channels in the east. In some of these channels excessive flood water found its way which moved slowly on the very gentle gradients of the channels and deposited fine textured materials in their beds and even today though they remain dry practically for the whole year, have what we call internal drainage. Fine sediments washed from the adjoining dunes are also deposited in the beds of these channels. The Indus river finally moved into the sub-recent flood plain, with the result that fine sands were deposited in this area. At this time the rainfall of the regions was higher, due to which some of the sand dunes became stabilized.

During middle Holocene, the sand ridges were weathered and became somewhat more stabilized, vegetation started sprouting on them, old channels

HOLOCENE			Middle and Late	Soil formations in ThaI continues. Winds reworking soil formation in the newly abandoned flood plain of River Indus in the West. In the South-Western margin of ThaI reworking of sand deposits takes place. Continuous shifting of Sand from rivers and ThaI area taking place. River Indus continues to shift westward.
	10⁴		Early	Stabilization of sands by establishment of vegetation and Soil formation in parts abandoned by rivers. Down cutting of Indus river to a smaller gradient starting from the North. Deposition of Loamy material mainly in the South Western margin of ThaI. Deposition and wind reworking of sandy piedmount sediments in Western areas.
PLEISTOCENE	[illegible]	[illegible]	[illegible]	Continued deposition of sandy material (part from the Western Potwar uplands and part from the Himalayas in the ThaI Area. Wind reworking of Areas abandoned by Indus River).
	[illegible]	[illegible]	[illegible]	Deposition by strongly seasonal Indus river of sandy ThaI sediments, and wind reworking of areas abandoned by river. Fines blown out to form loess.
		[illegible]		Soil formation, deposition by river, and probably wind deposition.
		[illegible]		Deposition by rivers, and probably wind reworking of mainly sandy sediments from actively eroding Himalyas and uplands.

of the Indus continued, but normal filling of the channels through fine sediment deposition continued.

During this period as the Indus continued to shift its course westwards, flood inflows in the area continued depositing fine textured material in the cover flood plain zone. Due to fluctuation of groundwater the formation of Kankers in the upper mantle of fine textured material took place.

In the late Holocene as the deposition of sediments with the subsidence of the Punjab dry geosyncline continued, somehow, some dipping of the cover flood plain to the south west took place.

With the onset of recent time the climatic conditions were somewhat modified and the Indus acquired its present course. Large sand deposits were laid down on the flood plains of the Indus which during dry periods started shifting to the main doab through the agency of wind. Dune formation started taking place in the areas with less vegetation. Interdune areas having their own local drainage system started accumulating fine textured material from the adjacent dunes.

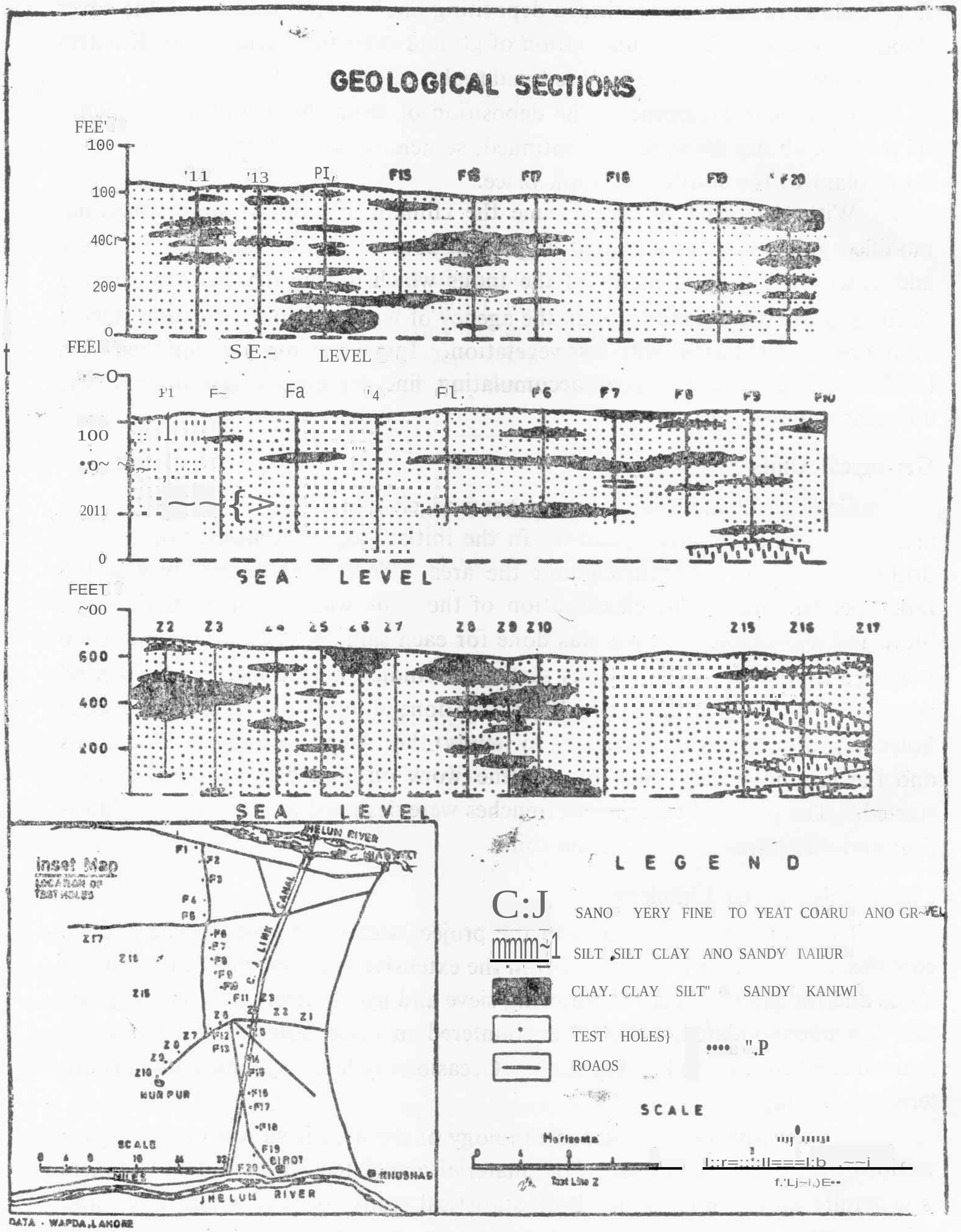
Geological Units

Geological and soil investigations and classifications of material of the area were done in three phases. In the initial stage 6" diameter holes were drilled with hand auger throughout the area. Their average density was 1.5 holes per sq. mile. The classification of the soils was recorded on the logs. Sieve and hydrometer analysis was done for each sample, gradation curves were prepared and from them various statistical studies were done. In the second stage of work deep drilling up to 100 ft was done along the periphery and some holes were also done inside the area to study the deep geological formations and the ground water. Side by side the work on pits and escarpment also started. The pits and escarpment trenches were designed to study the stra~ification and structural features of the soil.

Characteristics and Lithology

The major geological unit in the project area is late plesitocene alluvial complex are shown in Figure 8. From the extensive study carried out of logs of bores and the gradation curves showing sieve and hydrometer analysis it appears that the unconolidated, material encountered in these holes ranges from fine grained sand to silty and clayey sand. Occasionally fine clay lenses are encountered at varying depths.

The distribution of various lithology of the area is shown on geological sections and panel diagrams. Fine material associated with limited kankers is generally mostly fine sand. Both statistical study of the grain size, and the comparisons of the gradation curves of the project area with the adjoin-



DATA - WAPDA, LAHORE

Fig. 8.

iug area in Thai Doab clearly indicates that the material lying within the is very similar geologically to the material found in the adjoining parts of the Doab. There are some regional variations in the gradation of the material.. The sediments encountered in the exposed and covered channel remnants show on the whole a slightly high percentage of fine material with clay as compared to the material of the rest of the area.

Nature and Depth

The study of the bore hole log data, the sections and the pannel diagrams indicate that at least upto a depth of *800* ft. the alluvium in down stream as well as in transverse direction is heterogeneous.

Sand

The sand occurring in the area is fine to medium grained, average size is (50-100) micron. Major minerals of sand are quartz 50-60%, Feldspars 12-19%, Mica 15-30% and few heavy minerals. The sand grains are poorly to well sorted. The sand grains are not well rounded and most of them have subangular to subrounded shapes.

Permeability determined on disturbed samples in the laboratory ranges from 6.2 x 10 to 4.7 x 10 ftjsec. The test drilling indicates that the sand layers are locally compact to semicompact and the sand grains hold together due to the presence of small amount of clay and silty material.. The proportions of fines i.e. clay and silt in sand ranges from 10-40% and in field it is identified as silt sand and clayey sand.

Silt

The silt is grey to greyish brown, lighter colours also occur. The average grain size is 12-50 micron. The coarser silt grains generally have the same mineralogical compositions as fine sand. The silt is generally found associated with sand and clay.

Clay

Clay is grey brown to earthy brown in colour. In dry condition it is hard and brittle, while wet it becomes stickly and plastic. Clay generally occurs in lenses in the area in constitute 25 to 30% of the total alluvium. This reduces the vertical permeability to almost half. Some of the soil samples were analysed in the Punjab University Laboratory. These samples were treated with 0.2 NHCI to recome carbonates and with H_2 O_2 to remove organic matter. There was 20 to 11%, CajCO],. Then calculations were made on the basis of *100*%, with treatment, the clay fraction was increased from 12 to 28% in the samples with the resultant variations in other constituents. The result obtained in the sieve and hydrometer analysis without treatment with 0.2

HCI (removal of carbonate) should be looked as if the clay and silt fractions that have been reported to us by the MS & F Laboratory are on the very low side.

Salts

Chemical analysis of the soils also indicates presence of sodium salts in the soil which has led to a high concentration of the exchange complex with changes in the properties in a favourable way leading to deflocuIation and consequent lowering of permeability of soils. In our opinion the presence of these salts has a special effect on individual clay particles that they cement particles to silt fractions, and thereby showing a large unrealistic proportion of sand in the area. Eolian sand in the area overlies the flat fluvial deposits throughout. Several sand forms such as, sand veneer, sand drifts, sand undulations, knob dunes, longitudinally aligned sandy ridges, and wave barchan like dunes have been identified and mapped. The sand in the area geologically speaking seems to have been formed over the last few thousand years. It is possible that the eolian sands in the area may have been originally deposited as alluvium by the Indus and Jhelum rivers, later these deposits may have been reworked by wind action forming the present sandy topography. Active flood plains of the Indus and Jhelum rivers during low water periods may also have been a large source of sand for the region.

Generally the aeolian sand in the dunes is loose and unconsolidated with high permeability. The large dunes in the southwestern project area which have growth of vegetation on them are generally which seems to be the major factors in binding the sandy material together.

Lithologic changes **and** permeability

Many aspects of the hydrology and geology of the area are closely related. Variations in the water bearing characteristics of the alluvium are in general agreement with observed lithological changes in the area and in the Doabs as a whole. Average lateral permeability for pure sand of the Thai Doab is 0.0033 cusec per sq. foot. Whereas 68% results fall in the range of 0.0017 to 0.0037 cusec per sq. foot. The permeability values determined by a pumping out test in the middle of the area at Rakh Jamali is 0.0017 cusec per sq. foot. Since the geology of the Rakh Jamali is the same as the rest of the area, we can safely assume this value for the rest of the region.

Permeability was also determined on 32 disturbed samples from varying depth which indicates moderate to low values of permeability;

Ancient Fluvial Channels

Within the area some surface depression forms have been mapped which are elongated longitudinally. These depressed areas have been demarcated through the air photo interpretation and filed evidence as the ancient fluvial channels (Fig. 9). These channels in the area are completely dry and are under intensive cultivation. The channel located to the west of Nurpur is thoroughly exposed, only in few places it is occupied by Barchan type of sand dunes whereas the channels located in the neighbourhood of Jamali and south of Shergarh are covered with sand undulations. The beds of these two channels have thick veneer of sand which may be 5'-10' thick, but the thickness of sand varies from place to place.

As it becomes abundantly clear from the study of the logs of the deep borings that the material beneath the complex of sand dunes was deposited by fluvial processes the water streams which laid down the thick deposit of alluvium in the areas were mighty river Indus and Jhelum river which during late pleistocene times may have carried abundant discharge and must have flowed at higher

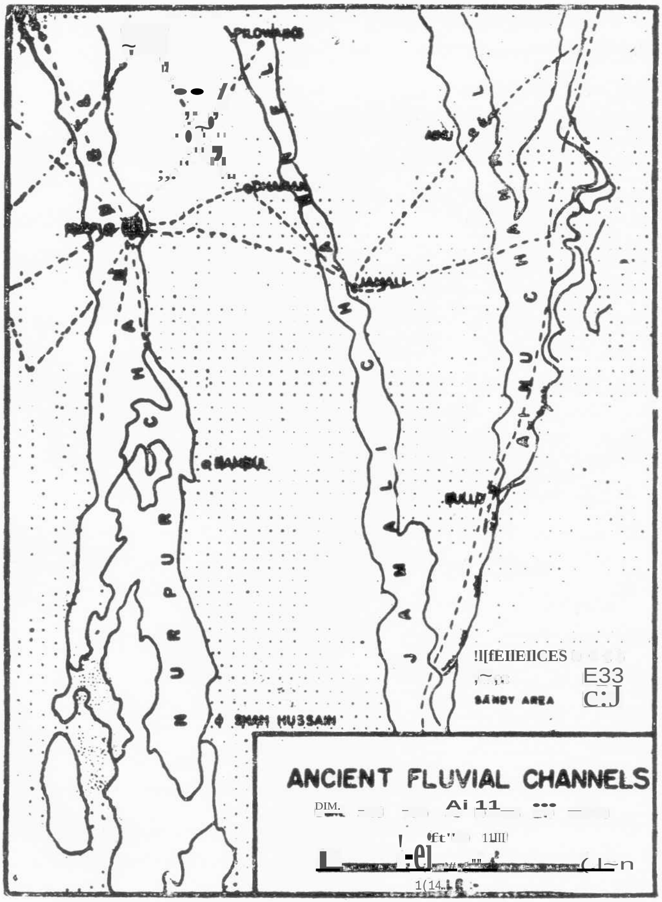


Fig. 9.

velocities and in bigger channels and deposited these alluvial sediments which we encounter in the area. Fast flowing rivers and carrying large sediments load generally deposit coarser mlterial in their beds as compared to the rivers of low discharge which generally flow slower and deposit comparatively fine material. The river indus as it deposited its bed loads also continued migrating west-ward leaving behind abandoned flood plains and abandoned channels which carried water during high floods. These channels also served to carry local runoff water from the central parts of Doab to the south into the master streams. Both flood water and local runoff water constituted low discharges, therefore, the sediments deposited in the bottom of these channels, were mostly of fine textured material with high percentage of clay and silty components. The auger holes penetrating these deposits clearly exhibited finer lithology in the upper parts of the alluvium, at depth, medium to fine sandy material continues.

Based on their locations in the neighbourhood of major settlements the channels have been designated as;-

The Nurpur Channel
The Jam'lli Channel
The Ainu Channel.

The Nurpur Channel

Nurpur Channel is located to the West of Nurpur where it is about 2 miles wide. The own of Nurpur is located in the channel itself. From Nurpur it extends southward upto katimar, throughout its southward continuation its width remains about 2 miles. From Nurpur it follows roughly the alignment of Nurpur Adhikot road. The relief of its bed is almost flat studded with sand dunes here and there. The bed generally contains clayey and silty material (Fig. 10).

The channel has remained under human use for centuries. The fact is supported by the presence of ancient places of human dwellings such as forts and old houses and settlements. Within the channel there are areas of good clays which has been mined for pottery and brick making. Most of settlements located in the channel area are built with burnt clay bricks. The bricks are of very fine quality and very tough to break. The appearance of fine clay deposits within the channel is indicative of minor channels within the master channel. In the last stages when generally dry conditions prevailed the runoff and flood water considerably dwindled, then perhaps a small channel within the ancient channel continued to receive water and thus laid down these fine deposits of clay in the master channel.

Within the Nurpur channel extensive cultivation is practised and this area is regarded as the most agriculturally productive region of Central Thai Doab, local people refer it as Patti' land.


NURPUR
NURPUR
71-55
31-56
31-55
71-55
0
1
2
Miles
+ ELIVATION
— — DRV HALLAH
— DEPRESSION
- - - TRACK

Fig. 10.

The demarcation and its lateral extent generally becomes difficult and the 'Patti' area gradually merges into the dune country. However, on the margins of the 'Patti' land the density of the dunes and their height generally increases. This is due to a sudden break in the surface wind which retards the velocity and results in the deposition of thick sand on the margins.

The Jamali Channel

The Jamali channel runs longitudinally in a north south direction. (Fig. II). The encroachment of the shifting eolian sand has made its surface somewhat obscure. To an observer in the field it is rather difficult to delineate the channel boundary. Scattered fixed eolian sand dunes which are scantly covered with shrubs and grasses have to some extent stabilized the dunes in some parts of the channel. This characteristic of land having rather comparatively thick vegetation cover and stabilized dunes has created a unique topography of undulating nature which continues along the channel. Within the swarm of these dunes are also present extensive patches of flat land which are devoid of dunes. Large areas of the Jamali channel are also under cultivation. Practically all the settlements located in the channel have pacca brick housed. The bricks have been made by mining of clay from the bed material. Within the channel there are localized deposits of clays of high plasticity. Perhaps these clayey deposits are lenticular in shape.

600 feet contour line almost runs parallel to the channel. Northward extensions of the channel, north of Jamali, could not be ascertained due to poor coverage of aerial photograph. The photographs are too hazy to give any clear boundaries. However, the boundaries have been tentatively arrived at by using converging field evidence.

The material of channel is composed of clay, silt and fine sand. Fines constitute 30 to 35%. This formation generally continues up to a depth of 10 feet from the N. S. L. of the bed. The sediments of the channel are grey to greyish, brown; comparatively from the surrounding area the channel material has more fines.

In a desert region like this, stranger is often confused when he crosses brick culverts across the sandy road leading to Jamali. These culverts are indicative, that in the recent past at least, during the rainy season, some water was available within the channel in such quantities that the road could only be crossed through culverts. Few miles east of Jamali a large water storage tank is also located perhaps this tank stores runoff water from the master channel for use during the dry season.


72-5
JAMALI
JAMAL
31-50
31-50
72-5
0
1
MILES
+ ELEVATION
DRY NALLAH
DEPRESSION
TRACK

Fig. 11.

Ainu Channel

The Ainu channel enters the area north west of Ainu from C-J Link side. The channel is wide and slopes south east. It drains into the Jhelum river near M. S. 39-40. Its slope is less than 1 foot/mile to the south of Ainu. The floor of the channel in places is covered by thin veneer of sand and undulating sand dunes. Walking on the thin veneer of sand gives an impression, that the base on which the find material which is generally, silty and clayey. On the airphoto both tonal differences, micro-relief features aid in the delineations of the boundaries of the channel. Not all the surface of the channel is covered with sand at places the hard compact surface with silty clayey sandy material is exposed, the sand from these areas has been removed and redeposited in the dune areas. The examination of the auger holes and pits data reveals that the bottom of the channel beneath the veneer of sand is composed of silty clayey sandy material. The clay percentage is 10-15 % on the average. The silt ranges 15 to 20 % and such fine sand is less than 70 %. The microrelief pattern and the morphological characteristics of the Ainu channel are indicative of fluvial environments of slow water movement in the channel.

CONCLUSION

Sediments of the study area consist of fine to medium grained sand, with small quantity of silt and clay. The basement sediments of dunes were laid down in the area by the present and ancient drainage systems by fluviatile action. The remnants for some of the former drainage channels can still be noticed. The eolian deposits superposed on alluvium have variety of shapes and pattern. The depressions which are free from sand are perhaps due to concentration of runoff water in them. Most of the dunes received the sand from the active flood plains of Indus and Jhelum rivers, and the alluvial plains. The river sand and the alluvium contains calcium carbonate, which is also found in the dune material. To a certain extent this may support fluvial origin of the sediments in the area which are now being reworked by eolian action. Although some vegetation exists but is not able to stabilize dunes. Some dunes when exposed by winds show in the core a former stable and consolidated dune structure. The sand undulation and Barchans keep on shifting their position in successive years. Erosion in former fixed dunes continues. Major characteristics of the alluvium and its lithology has been inferred from a study of samples of a number of geologic logs of augar holes and deep holes drilled in the area. These logs confirm the heterogeneous character of the upper most 100 feet of the alluvium and random distribution of clay zones. A study of the sections across the study area indicates sandy and relatively permeable alluvial material with clay lenses in the alluvial deposits.

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