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Irrigation and Field Patterns in the Indus Delta.

Mushtaq-ur Rahman

Louisiana State University and Agricultural & Mechanical College

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IRRIGATION AND FIELD PATTERNS
IN THE INDUS DELTA

A Dissertation
Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

in
The Department of Geography and Anthropology

by
Muzhtaq-ur Rahman
B. A. Hons., M. A. Karachi University, 1955
June, 1960
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ABSTRACT

Present irrigation practices and field patterns in the Indus delta are the result of a long process of trait introductions from without and adaptation and development of cultural patterns within. Through the historical approach, generic relationships of some present patterns are traced to their origins while other pattern origins have been lost.

As a result of the antiquity and wide distribution of irrigation, its origin remains uncertain. It was probably somewhere in small alluvial valleys of Southwest Asia, which is considered the hearth of seed agriculture and which provides the maximum geographical conditions for evolution of basin irrigation. Basin irrigation, which utilizes the overflow of rivers, is the simplest and oldest form of irrigation used by prehistoric civilizations, especially those of Egypt and the Indus Valley. From this simple beginning various techniques of irrigation evolved to serve different natural landscape conditions. Irrigation practices in the Indus delta are divided into three major types: basin irrigation; lift irrigation, wherein water is raised artificially from subterranean and surface water sources; and canal irrigation.

Cultural factors introduced by peoples migrating into the Indus Valley largely explain the present irrigation patterns. Basin
Irrigation was introduced from Southwest Asia probably shortly after the domestication of crops. Elaborate water wells were constructed in the Indus Valley by 3,000 B.C., but they were probably used only for drinking purposes. In 712 A.D. the Arabs introduced the nar (Noria or Persian Wheel), an important device for lifting water from the river, canals and wells. Basin irrigation partly gave way to canals, a more effective technique of irrigation during and after the regime of Kalhora dynasty in the eighteenth century.

Irrigation practices, agriculture implements, trails, roads, land tenure systems and rice culture have all affected the present field patterns of the Indus delta. The fields are fragmented, generally small in size and are rectangular, square or irregularly shaped.

The village and hamlet settlement patterns are directly related to agriculture development and practices. Their form, distribution, and function are a product of the cultural milieu of the area. From ancient times small nucleated settlements spread coincidental with new agricultural areas. The settlements grew both for mutual protection and for their convenience to fields. Villages are located along larger abandoned and active Indus River distributaries presently used as canals, whereas hamlets are found along smaller distributary canals. Both the village and
hamlet are located in close proximity to the agricultural fields.

The natural setting of the arid Indus delta imposes certain challenges to man's ingenuity. During the summer the river floods with a surplus of water, while during the winter the river is in low-stage with a deficiency of water. The extensive use of the nar with wells provide water for the fields during the winter months. Recently barrages and artificial levees have been constructed to control water during the summer floods and to supply water to canals and ditches during the winter. Irrigation practices and settlement patterns are an expression of man's activities in a challenging milieu.
I. INTRODUCTION

This dissertation is a study of irrigation and field patterns in the Indus delta, with emphasis on their origin and introduction into the area. Natural and cultural factors accounting for prevalent irrigation practices and field patterns are considered. In the physical milieu climate, landforms, soils, river stages and hydrographic changes are significant. Cultural succession is discussed to establish the age and development of irrigation techniques. Emphasis is largely on the patterns rather than processes. To avoid a chronologic historic treatment, only the events important to the development of irrigation are considered. There is also a limited discussion on the pattern of settlements adjoining the canals and fields, notably those along the Kalri canal (Map 1).

An archaeological and historical approach is necessitated by the nature of the study; that is, tracing the origin, diffusion and subsequent inventions of irrigation techniques. Data from the Indus Valley civilization sites is primarily used but a comparative study of irrigation patterns in the Indus Valley civilization with those of Egypt and Mesopotamia is required to draw similarities and differences. Through the haze of antiquity and wide distribution of irrigation in Southwest Asia the specific place of origin remains unknown.
Archaeology of the Indus Valley civilization and older sites in West Pakistan shows agriculture practices as far back as 4,000 B.C. Since no clear material evidence revealing the methods of procuring water for agriculture was discovered, eminent archaeologists like Mackay (1948, p.77), Wheeler (1958, p.9), and many others sought the explanation in wetter climates which were believed to have existed during that time. Evidence indicates that there has been no notable change of climate during the past 6,000 years, and confirms the idea that agriculture flourished with the aid of basin irrigation.

Research further indicates that irrigation is as old as agriculture in the Indus Valley. Most techniques for obtaining water, including irrigation, were introduced from the west by penetrating cultures. The irrigation patterns in the Indus delta are divided into three distinct types: basin irrigation, canal irrigation and well irrigation. This study deals primarily with these types, together with the changes enacted on them through time by penetrating cultures.

Field patterns present a far greater complexity in attempting a generic treatment. Besides the impact of irrigation and settlements, influence of other pertinent material elements such as agricultural implements, wheeled vehicles, and rice cultivation is discussed. Non-material traits such as land tenure, economic and political aspects, and social organization are also considered, since they are
connected with the evolution of small fields and the composition of the cultural landscape.

Field work done during the years 1955 and 1956 was supplemented by library research in the British Museum, India Office, and India House libraries at London, during the summer of 1957. Library research was further extended at the Hill Memorial Library of Louisiana State University, and cooperating institutions, during the years 1958 and 1959. For literature other than English and French, a reading knowledge in Sindhi, Persian, and Arabic complemented and extended the library research. Aerial photographs supplied by the government of Pakistan provided a base for some maps and enabled a more detailed study of field patterns and the physical base.

A general diversity of views among preceding writers exists regarding the delta boundary. Heddle (1836) and Carless (1837), notable among the early British writers, considered the area south of Tatta as the delta, precisely from the place where Baghar and Sattah distributaries leave the river (Map 1). Blanford (1880) and Haig (1894) deviated from the view and considered the extension of the delta as far north as Hyderabad. Modern writers (Wadia, 1953) and many others believe Tatta is the northern limit of the delta.

Following the generally accepted definition of a delta (Russell, 1936, pp. 3-4) the area south of the bifurcation of the
first major distributaries, Kalri and Pinyari (Map 1), is considered the delta of the Indus River in this study. Kalri flows to the west at the foot of the Karachi bedrock plain and merges into the sea beyond Lahori Bunder. The contact between the Recent alluvium and the Karachi bedrock plain forms an escarpment and is a well-marked physiographic boundary and is adopted as the western limit of the delta (Map 1). The eastern boundary is formed by the Pinyari, which flows almost in a straight north-south direction through an older flood plain of the Indus River (Map 1).
II. PHYSICAL SETTING

The physical setting of the Indus delta is diverse. The climate is arid maritime with variable rainfall that averages about eight inches per year. The small amount of precipitation and its variability makes it mandatory to irrigate for crop growth. The low relief of the delta area is in contrast to the higher Tertiary hills that bound the area on the west and the sand dunes that mark the beginning of the Thar desert to the east.

The Indus delta is marked with numerous active and abandoned channels of the Indus River. The active and abandoned channels with their adjoining higher banks, sand bars, and mudflats are the conspicuous landforms. The high range of the seasonal river stages has made it possible to develop an extensive system of irrigation based upon inundation canals. Soils reflect a great complexity in texture from place to place depending upon their depositional environment. Soil salinization imposes limitations in the older irrigated areas, and toward the coast high tides have built extensive mudflats and transport saline water far inland.

Weather and Climate

The weather and climate of the Indus delta embody most of the characteristics of an arid maritime climate; seasonal influence from the sea; high but not excessive temperatures; and little rain-
fall. The most striking feature of weather and climate is the variability in amount and time of rainfall. Rains occur mostly in the summer season but the amount and time vary to the extent that during some years the rainfall doubles the average, while in others it drops considerably.

Owing to the paucity and unreliability of weather data, even a gross description of the Indus-delta climate is difficult. Map 2 indicates that out of the eight weather stations including the ones in the immediate vicinity of the delta only two, Karachi and Hyderabad, have a record of more than twenty years. Three weather stations, Tatta, Hilaya, and Jhimpir, were established by the government of Pakistan in 1955 with inadequate equipment and untrained personnel; data recorded at these stations are usually fragmentary. The means of the data recorded by these stations have been published for a two-year period. For the remaining stations only rainfall figures are available from the Annual Irrigation Reports and District Gazetteer.

Temperature and rainfall are the two most important climatic elements which influence the irrigation pattern in the Indus delta. Humidity and sunshine affect the evaporation rate and are important considerations when dealing with temperature and rainfall. Hence temperature, humidity, and precipitation deserve special consideration.
Temperature

Air temperature recorded by weather stations in the Indus delta is typical of most arid areas. The days are hot and the nights cool with average diurnal range as high as 22°F\(^1\) for most stations. Monthly mean temperature rarely exceeds 80\(^\circ\)F, average monthly maxima seldom pass 91.9\(^\circ\)F; and average minima infrequently go below 68.7\(^\circ\)F (Fig. 1). The hottest area corresponds to the northern limit of the delta, where stations record an annual mean of over 81.2\(^\circ\)F.

As would be expected, due to oceanic influence less extreme temperature prevails along the coast. For example Karachi has an annual mean of 78.4\(^\circ\)F, whereas Hyderabad records 81.7\(^\circ\)F.

The temperature begins to rise in March and remains high until October, which is regarded as the summer season. The beginning of the summer season is marked by an abrupt change in temperature from February to March, but the temperatures remain fairly constant during the summer months (Table 1), with May and June the hottest.

July isotherms (Map 3) have a latitudinal trend in the

\(^1\) Temperature figures are in Fahrenheit, unless otherwise indicated.
Fig. 1
Table 1

Monthly Temperature Means
(Figures in Fahrenheit)

<table>
<thead>
<tr>
<th>Months</th>
<th>Karachi</th>
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<th>Jhimpir</th>
<th>Hilaya</th>
<th>Hyderabad</th>
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<tr>
<td>January</td>
<td>77.1</td>
<td>50.7</td>
<td>69.9</td>
<td>74</td>
<td>47</td>
</tr>
<tr>
<td>February</td>
<td>80.5</td>
<td>54.7</td>
<td>67.9</td>
<td>81</td>
<td>48</td>
</tr>
<tr>
<td>March</td>
<td>87.9</td>
<td>63.1</td>
<td>75.5</td>
<td>89</td>
<td>60</td>
</tr>
<tr>
<td>April</td>
<td>94.7</td>
<td>70.9</td>
<td>84.8</td>
<td>97</td>
<td>66</td>
</tr>
<tr>
<td>May</td>
<td>95.3</td>
<td>78.2</td>
<td>86.2</td>
<td>99</td>
<td>75</td>
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<tr>
<td>June</td>
<td>95.4</td>
<td>82.1</td>
<td>88.7</td>
<td>97</td>
<td>79</td>
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<tr>
<td>July</td>
<td>90.8</td>
<td>80.8</td>
<td>85.8</td>
<td>92</td>
<td>79</td>
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<tr>
<td>August</td>
<td>88.2</td>
<td>78.8</td>
<td>83.5</td>
<td>89</td>
<td>77</td>
</tr>
<tr>
<td>September</td>
<td>89.8</td>
<td>76.8</td>
<td>83.8</td>
<td>90</td>
<td>75</td>
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<td>59.8</td>
<td>74.8</td>
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<td>December</td>
<td>80.9</td>
<td>53.0</td>
<td>66.9</td>
<td>78</td>
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Source: Karachi and Hyderabad data from the files of Pakistan Meteorological Department.

delta due to oceanic influence but change to longitudinal direction roughly north of Jhimpir. In the central and northern parts of Sind the mean temperature rises much more than in the delta (Khan, 1954, p.2). The temperature falls rapidly in November which marks the beginning of the winter season (Table 1). Winter prevails from November until February with January as the coolest month. January isotherms indicate pockets of comparatively low temperature around Tatta, Mirpur Batoro, and high temperatures around Jhimpir, and Hilaya (Map 4). These conditions become more pronounced in February and continue into March. The origin of these high and low temperatures in localized areas is associated with the western depressions which affect the area and will be discussed later.

Relative Humidity

Relative humidity is exceedingly high in the delta as compared to the humidity in central and northern Sind. Table 2 gives average relative humidity figures at 3 o'clock in the morning and 12 noon for each month on two years average at Tatta. Humidity percentages are higher in the early morning hours during the summer months because of the lower temperatures. With rising temperatures toward noon the relative humidity decreases.
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<td>77</td>
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<tr>
<td>February</td>
<td>81</td>
<td>26</td>
</tr>
<tr>
<td>March</td>
<td>83</td>
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<td>April</td>
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<tr>
<td>May</td>
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<tr>
<td>June</td>
<td>74</td>
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</tr>
<tr>
<td>July</td>
<td>81</td>
<td>67</td>
</tr>
<tr>
<td>August</td>
<td>79</td>
<td>81</td>
</tr>
<tr>
<td>September</td>
<td>Not available</td>
<td></td>
</tr>
<tr>
<td>October</td>
<td>78</td>
<td>49</td>
</tr>
<tr>
<td>November</td>
<td>65</td>
<td>67</td>
</tr>
<tr>
<td>December</td>
<td>77</td>
<td>47</td>
</tr>
</tbody>
</table>

Precipitation

Low precipitation is the chief characteristic of the Indus delta which in terms of amounts averages about eight inches annually. Because aridity has been a continuous problem to man in this area various supernatural and scientific explanations have been offered for the low value of precipitation. Hindus of Sind have a tradition that Hiranyakasipu, the demon king of Multan, was powerful enough to draw down Megha Raja, the cloud god from heaven and compel him never to visit the Indus Valley (Burton, quoted by Pithawalla, Pt. III, p. 20). Pithawalla (ibid.,)believes orography is the sole cause of aridity. According to him the surrounding hill range which is about 2,000 feet high produces no
Simpson (p. 158) says that two factors, the great temperature, and the direction of upper air current, account for the low precipitation. According to him,

"...throughout the monsoon, the upper air over northwest India blows from west and northwest off the hills of Baluchistan and Afghanistan. This upper air current is warm and very dry. Its humidity was as low as 20% and the dry air extended downwards to about 2500 ft. above the ground level. The air near the ground has a high humidity as it crosses the Sind coast, but it warms up considerably as it passes inland from 85 at Karachi to 95°F at Jacobabad - so its humidity decreases from 80% to about 55%. The air over northwest India would have to rise 3,000 feet above before condensation takes place, but before it reaches the height it has encountered the upper dry current from the west, and in consequence no cloud is formed over the region of low pressure."

Simpson's explanation is accepted by Kendrew (p. 115) and Miller (p. 149).

The Indus delta receives about five inches of rainfall from the southwest monsoons in the summer and three inches from the western depressions in the winter. Until recently the southwest monsoons were thought to originate due to the low pressure development over the subcontinent of India and Pakistan by the relative movement of the sun over the northern hemisphere in summer. By the end of May or early June a low pressure area extends over Sind and Punjab (Banerji, p.10). The presence of low pressure over the subcontinent was believed to initiate the flow of air
from the oceanic high resulting in the southwest monsoons. However, according to present views, southwest monsoons result largely from the northern migration of the Equatorial trough during the summer. As the summer season advances, the northern limit of the Equatorial trough separating the air masses of the northern and the southern hemispheres moves northwards and sets the stage for the flow of the southwest monsoons. By April the Equatorial trough reaches the Equator (Naqvi, 1959, p. 52) and by July covers a wide band from 2°N. to 27°N. latitudes (Riehl, p.12). In June, subtropical anticyclones of the south Indian ocean shift westward with its center near 30°S. and 60°E. The Westerlies of the "Roaring Forties" in the southern hemisphere sweep around this anticyclone and become the southwest Trades. These and the subsiding air masses in the northern part of the anticyclone blow on steadily from the southeast until they cross the Equator where they are deflected to the right by coriolis force and become southwest monsoon winds (Naqvi, ibid., p. 52).

Southwest monsoons furnish copious amounts of rainfall to other parts of the subcontinent but fail to produce rain in the Indus delta and adjoining areas due to an inversion aloft of warmer continental air. By May the inversion occurs between 3,000 to 5,000 feet above the surface and is caused by the colder
maritime air of the Equatorial trough wedging in beneath it. The intensity and height of the base of the inversion layer appears to increase as the summer season progresses; by July and August it attains a height of 5,000 feet. The inversion layer acts as a lid and prevents the penetration of rising convectional currents from below (Rao, p.1).

In an east-west direction the inversion layer extends from the Makran coast to the Runn of Cutch. Extending inland the inversion layer rises from 3,000 feet at the coast to 5,000 feet at Hyderabad and 10,000 feet at Lahore where convection currents are no longer prevented from rising.¹

Crowe (1951, pp. 61-62 and 1956, pp. 5-6) has also ascribed the low value of precipitation to this overhanging hot continental air which prevails over the area from 4,000 to 10,000 feet.

July, August, and September are the rainiest months of the summer with a total rainfall of about five inches but with a high variability. Variability of rainfall is an outstanding characteristic of the Indus delta climate. Table 3 represents the annual rainfall variability at four stations for the years 1919-1922.

¹ Data from verbal communication with Rodman E. Snead, graduate student, Louisiana State University, 1959, who has recently conducted field work in West Pakistan.
Table 3

<table>
<thead>
<tr>
<th></th>
<th>Variability of Rainfall</th>
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<tr>
<td></td>
<td>(Figures in inches)</td>
</tr>
<tr>
<td></td>
<td>1919</td>
</tr>
<tr>
<td>Tatta</td>
<td>7.01</td>
</tr>
<tr>
<td>Mirpur Sakro</td>
<td>8.05</td>
</tr>
<tr>
<td>Keti Bunder</td>
<td>4.72</td>
</tr>
<tr>
<td>Shah Bunder</td>
<td>17.09</td>
</tr>
</tbody>
</table>


The rainfall variability is far greater during the individual months than yearly means represent. Tables 4 and 5 show the monthly rainfall figures from 1940 to 1945 at Karachi and Hyderabad stations and represent the rainfall variability for individual months.

Naqvi (1958, p.1), Director of Pakistan Meteorological Services, has calculated the annual and monthly variability of rainfall at Karachi for a hundred-year period. According to his calculations, the coefficient of variability of annual rainfall is 13 per cent, while the variability of individual months vary from 137 per cent in January and July to 567 per cent in April and October with intermediate values in the intervening months.*

During the winter season, the Indus delta receives about three inches of rainfall from western depressions and Arabian-sea
### Table 4

**Monthly Totals of Rainfall at Karachi**  
*(Figures in inches)*

<table>
<thead>
<tr>
<th></th>
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<td>2.12</td>
<td>1.40</td>
<td>1.41</td>
<td>0</td>
<td>0</td>
<td>0.55</td>
<td>3.0</td>
<td>1.84</td>
<td>0</td>
<td>0</td>
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<tr>
<td>1941</td>
<td>0.03</td>
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<td>0</td>
<td>0</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0.03</td>
</tr>
<tr>
<td>1942</td>
<td>0.6</td>
<td>1.24</td>
<td>0.06</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.16</td>
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<td>1.19</td>
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<td>1943</td>
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<td>0</td>
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<td>10.27</td>
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<td>0</td>
<td>0</td>
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</tbody>
</table>

*Source: Data from the files of Meteorological Department, government of Pakistan.*
Table 5

**Monthly Totals of Rainfall at Hyderabad**

(Figures in inches)

<table>
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<tr>
<th></th>
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<td>0.02</td>
<td>0.66</td>
<td>0.96</td>
<td>2.90</td>
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<td>0</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6.14</td>
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<td>0.12</td>
<td>0</td>
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<tr>
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<td>0.02</td>
<td>0</td>
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<td>0</td>
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<td>0.75</td>
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<td>0.17</td>
<td>0.12</td>
<td>0</td>
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</tr>
</tbody>
</table>

Source: Data from the files of Meteorological Department, government of Pakistan.
cyclones. The name western depressions was originally used by the Indian Meteorological Department for the disturbances which came from the west and moved eastward (Banerji, p. 3). With the solar reversion to the southern hemisphere, the thermal low over the northwest part of the subcontinent is gradually wiped out by the recession of southern-hemisphere monsoonal air and the gradual establishment of a large anticyclone over India and West Pakistan, 6000 feet above the surface. West Pakistan comes under the influence of predominantly westerly winds, which sweep as far as 15°N. latitude in mid-winter. A series of subtropical migratory anticyclones develops to the west over Arabia and the Iranian plateau and moves eastward throughout the winter season (Ahmad, 1958, p. 1). Some of these depressions originate locally but a large number of them move in from the Mediterranean sea through North Arabia and Iraq (Malurkar, pp. 202-205). The movement of such depressions results in cyclonic storms and temperature changes which are discernable on the January map (Map 4).

The Arabian-sea cyclones originate between 8°N. and 20°N. latitude and hit the area in November and December (Normand, pp. 8-10). This rainfall received in winter varies considerably and depends on the intensity and number of storms. At times, when the Arabian-sea cyclones are strong, they create havoc
through high winds, torrential rain, and strong storm waves from the sea.

Generally the winds are gentle in the area. In the summer the prevalent direction of wind is from the southwest with an average velocity of 7 knots. The maximum velocity is in June and July when 17 knots is recorded and the minimum in November and December when the velocity drops to 3 knots.

Landforms

The Indus delta, a westward extension of the Indo-Gangetic depression, which slopes gently from sea level toward the Himalaya mountains (Hayden, p.167). Recent alluvial deposits in the delta cover older Pleistocene sediments which overlie Tertiary rocks. The total thickness of the alluvial deposits is not known but from the few borings that have been made, the thickness of alluvium appears to be more than 1,300 feet below the ground surface and 1,000 feet below sea level (Wadia, p. 337).

The present active Indus delta is bounded on the west by the Karachi bedrock plain, a continuation of the Lakhi range and the north-south trending Kirthar range. According to Pithawalla (1936, Pt.1, p.295) the Lakhi range is a steep anticlinal fold, faulted with its upthrow towards the west exposing a prominent escarpment. The gentle eastward dip of the Lakhi beds is about
50 feet high bordering the immediate northwest area of the delta. The Indus River has eroded steep cliffs along its western contact with the older rock, and several remnant outliers remain in the delta. Predominantly, Lakhi range is composed of Tertiary deposits but in some sections Cretaceous rocks are found (Blanford, p.122). On the eastern side of the study area the deltaic plain continues but represents an older alluvial surface built by former courses of the Indus. The old delta to the east has been overlain by sand blown from the dry stream beds of abandoned river channels by the prevailing southwest winds. The term Sand Covered deltaic plain is used on Map 5 to distinguish it from the younger flood plain to the west. The Indus River presently flows to the sea through the approximate center of the delta area (Map 5).

North of the survey area the Indus River flood plain continues upstream forming a broad alluvial surface. No Pleistocene deposits have been mapped or recognized in the delta area. However, Pleistocene sediments are thought to exist on the flanks and as islands in the flood plain to the north near Hyderabad.

Landforms of the Indus delta are formed chiefly by stream deposition and scour of which natural levees, sand bars, lakes,

1 The term natural levee is used to designate overbank deposits which occur at favorable locations on the banks of the streams. Since the Indus River is a braiding stream the natural levees
INDUS DELTA

LANDFORMS

- Tidal Range
- Escarpment
- Levee Remnants
- Tertiary Rock
- Inter-levee Flood Plain
- Active Delta
- Sand Covered Deltaic Plain
- Sand Bars
- Lakes

Source: Aerial Photos, 1952-54.
tidal channels, and mudflats are most conspicuous forms. In the north and west corner of the survey area there are a few isolated Tertiary hill remnants that stand as the most conspicuous landform in the delta area (Map 5).

As previously defined the Indus deltaic plain extends from the Kalri canal on west to the Pinyari canal on the east. Due to man's activities, river processes and the effect of Arabian sea tides, the deltaic plain reveals varying characteristics, and is subdivided into: inter-levee flood plain, tidal delta, and the active delta.

The inter-levee flood plain designates the area on both sides of the Indus River within the two artificial levees (Map 5) where alluvium is laid every year. All of this land is inundated during the flood season and numerous changes in channel position and sand bars occur each year. During the low-water season the land surface is nearly level or only slightly undulating. The area beyond the artificial levees is not flooded annually. The artificial levees were completed around 1900, and terminate near the village of Kotri Allahrakhio (Map 1), where the main channel divides into the Ochito and Hujamri branches.

The tidal delta comprises about 60 percent of the region are generally without the characteristics found along streams like the Mississippi River, with continuous natural levees and well defined backslopes.
(Map 5) and is greatly influenced by the tides of the Arabian sea. The tidal range varies from 8.9 feet to 9.3 feet (Pakistan, 1959, p. 18), and penetrates from the coast to about 20 miles in the western section, 40 miles in the eastern section, and about 10 miles in the central section (Map 5). The eastern section is the oldest deltaic area of the Indus (Wadia, p. 390) and is lower in elevation as a result of lack of sediment supply and continued subsidence.

Along the coast tidal channels with intervening mudflats are the dominant forms. The mudflats are normally inundated by diurnal tides and are composed of silt and clay. They are locally known as the bhal lands.

The active delta covers about 25 per cent of the area and lies above the reach of high tide. It is generally higher than the tidal plains, with an average elevation of about 20 feet above sea level. The delta surface slopes gently from north to south and it is not known whether this is entirely due to sediment deposition or if there is geosynclinal sinking. The surface of the delta is traversed by many tortuous channels of abandoned and active distributaries of the Indus River. The result is the development of a low but uneven surface. Channel beds and the levees lie higher than adjacent land in many places.
Sand Bars

The Indus River and its active distributaries all have braided channels which form numerous sand bars (Map 5). The synonymous terms, anastomastic and braided, are used for the river characterized by successive divisions of the main channel and rejoining with accompanying islands (Leopold and Wolman, p. 40). The formation of a great number of sand bars in the Indus delta is associated with the periodic high and low stages of the river. When the Indus River reaches the flood stage and spreads from bank to bank, both erosion and deposition take place along its bed, at a terrific rate; material scoured in one place on the channel floor is deposited as a bar elsewhere. As the stage drops the whole process becomes less active, and finally the low-river water winds as best it can through the irregularities left on the bed as a result of the changes caused by scour and deposition of the preceding floods. When the volume of water is low in the river these bars appear more significant. Where the sand bars have become relatively permanent and have narrowed the channel in the Indus delta, as near the village of Khalifa, they are used as crossings by boat (Map 1).

Natural levees

The dominant constructional landform of the Indus deltaic plain is the natural levee. The natural levee is formed from deposits
of alluvium on banks during high-river stage. The higher banks are located discontinuously along the immediate stream banks and where undisturbed by man are conspicuous landforms. Along the formerly active Baghar channel, the natural levee remnant stands out prominently with a local relief of more than 18 feet (Map 5).

Lakes (dhands)

Lakes, locally known as dhands, are the expression of inter-levee damming (Map 5). During the flood season the lakes expand into broad but shallow sheets of water. The lakes on the western side of the delta are comparatively longer and are mostly aligned along the Kalri canal. Lenk-Chevitch (p. 8) has associated these lakes with an old buried channel of the Indus of Tertiary age. According to him the lakes are formed by wind corrosion, while the channel has been filled elsewhere by river and wind deposit.

The location of these depressions, however, suggests their origin can be traced to damming in inter-levee depressions. The water brought by the ephemeral streams from the western hills is dammed by the natural levees, making conspicuous lakes. This view is supported by the fact that some of these lakes are joined by streams from the western hill ranges.

Isolated Hills

A number of isolated hills surrounded by alluvium on all sides
are found mainly on the northwestern side of the delta. These hills are composed of poorly bedded limestone and shale strata of Tertiary age (Blanford, p.153). The largest of these is the cuesta-shaped Makli hills, with beds sloping gently to the west and southwest. The similarity with the western hill ranges in age and material suggests that these isolated hills are the outliers of the western hills and have been eroded in part by the rivers. Nothing definite is known about the origin of the hills but it may be inferred from the similar landforms in the Anatolian rivers (Russell, 1954, p.365), that these isolated hills with alluvium on all sides represent alluvial drowning in the delta. Similar hill remnants are found at Pir Patho, and other places in the delta.

These hills show considerable relief above the delta, and have been utilized by the Muslims as locations for mausoleums for native chiefs and religious leaders. The notion of a higher regard for deceased chiefs and religious leaders, common in Muslim society, have found expression in the hills to keep prominent people above the common people, even in death (Fig. 2).

Soils

A detailed soil survey of the Indus delta is not available and since no previous work has been done, only a general description can be made. Like other areas of arid climate
Fig. 2

Mausoleums at the top of a hill.

Note village settlement at base of hill.
(Simouson, p. 31) and Recent alluvial deposition, there are practically no profile developments in soils. The effect of pedogenic evolution is obliterated by climatic aridity and yearly addition of silt, leaving the mineral constituents predominant in the soil (Hodges, p. 67). The characteristics of the soil do not display any spatial differentiation except in texture and salt content.

Basically the soils of the delta are made of sands, silts, and clays. Insoluble silicates in sand and silt form more than 66 per cent of the constituents; the remaining 34 per cent are alumina, ferric oxide, salt, magnesia, and other minerals. The grains of the sand are generally small, varying from 1/10 of a millimeter to 0.0005 of a millimeter (Blatter et. al, p. 43). Different places, which largely conform to the landforms, have a different surface texture and suggest a workable classification which Map 6 represents. Generally the areas of higher relief, like the natural levees, are characterized by medium-textured soils while areas of comparatively lower relief have moderately heavy-textured soils. The finer materials are carried by the river into the tidal area where they are either deposited as mudflat material or carried to the sea.

The medium-textured materials are found predominantly on the natural-levee remnants of the deltaic plain and on sand bars of
the channels. Both medium and heavy-textured soils are thick, with no appreciable difference in material down to depths of 25 feet or more from the surface (LeVee, p. 9). Bedding plains which show strata of compact silt loam, silty clay loam, sand, or fine sand loams are encountered below the surface. These strata vary in thickness and arrangement from place to place, showing association with depositional environments. During some years heavy rainfall will produce high river stages and consequently more deposition takes place, while in others the situation may reverse. Tidal deltaic deposits are principally clays that have been reworked and deposited by the tides.

From capillary action soils have a fair percentage of free salt efflorescence in the delta area where less surface water is available. Soluble salts are widely distributed and sodium chloride is the predominant one. Concentrations of salts vary from place to place in the delta, in general depending on the water table, surface topography, and irrigation practices. Salt concentrations are highest where the water table comes within 10 feet of the surface during high river stages or at places where surface soil prevents active leaching. Local variations in salt concentrations occur from field to field, depending on the irrigation practice. Where irrigation is practiced, salts are temporarily flushed off to a depth below the root zone of crops,
and reappear on the surface when fields are left unirrigated for a year or so. The salt concentration is usually highest in the surface eight inches of unirrigated fields, although sufficient concentrations exist throughout the soil.

Analysis of water taken in various months from the river at Tatta shows a considerable amount of alkalinity (CaCO₃). The alkalinity percentage varies from 8.2 in June to 12 per cent in March (Lenk-Chevitch, p. 5). This will indicate that river water is the major original source of salt found in the delta soils. The salts are partly leached out at places where good drainage is present which also creates differences in salt concentration from place to place. There appears to be a definite correlation between land use and salt content of the soil. The areas which are under continuous cultivation have less salt whereas heavy salt concentrations are present in fields which are left fallow for a few years. In uncultivated areas, the surface is covered with salt efflorescence. However, in general terms LeVee (pp.10-12) has classified the soil near Tatta into three categories of salinity: slightly to moderately affected, severely affected, and very severely affected.

In slightly to moderately affected areas, the salt content is evenly distributed throughout the soil profile and ranges from 0.2 per cent to about 0.6 per cent. The principal salt is sodium
chloride. In the severely affected soils, salt content may exceed 1 per cent in the surface 8-10 inches, but rises again in the lower subsoil. In very severely affected soil, the salts show a high concentration throughout the profile. Concentrations often exceed 3 per cent.

**Changing Drainage Patterns**

Little is known about the details of river changes in the past, but it is generally believed that the oldest section of the delta is the eastern area. Since the build-up and abandonment in the east the river is thought to have flowed into the sea west of the present Indus River. The latest shift would place it in its approximate central deltaic position.

The deltaic plain is everywhere furrowed by past river channels, some of which show a continuous course throughout the delta, but others are obliterated with traceable courses showing for only short distances. Information available regarding the changes in distributaries before the British surveys is vague and unsatisfactory. An attempt is made to show the major changes which have taken place during the last hundred years.

The Alexander Burns (Burns, 1835) expedition of 1831 gives reliable information on the deltaic channels. This expedition was organized to measure the widths and depths of water in the Indus and its distributaries to determine their value as navigable streams.
No map remains from Burns' expedition, so no comparisons can be made with his work. The next survey was made by Heddle (1836), Carless (1837), and many other army personnel to gather further information on the deltaic distributaries. Carless made some scientific observations, did trigonometrical surveys in the area and made maps. Carless' maps were presented to the government of India in September, 1837, and are used here to compare changes in delta distributaries since 1837.

The Carless survey showed the Indus divided into two arms, Baghar and Sattah, about 50 miles from the sea (Map 7 A). Baghar on the west side of the river was then in a deteriorating condition and a sand bar was accumulating at its head and the Sattah, the eastern arm was the principal channel. The Sattah trifurcated into three channels, Hujamri, Kedywari and Teeteeah, before joining the sea. The first two, Hujamri and Kedywari, were navigable. Hujamri was flowing in a west-southwest direction in a winding course for an estimated distance of 40 miles to the sea.

The Kedywari left the Indus River 16 miles below the Hujamri trifurcation and flowed in the same general direction to the sea. Comparatively the Kedywari was then larger than the Hujamri. Carless observed four alligators 25 feet long lying on the bank of Kedywari, for the first time in his expedition to the Indus
1837
Modified from Carless, 1837.

1900
Modified from Aitken, 1907.
TRIBUTARIES 1837-1954

1954
Source: Aerial Photos, 1952-54.
delta. Alligators have since been exterminated. Teeteeah left the Indus 25 miles inland from the sea and joined the Richel River near its mouth before emptying into the sea. The Teeteeah was 30 yards broad and had a depth of one and a half to two feet during the dry season. Other branches, Mal and Mutni, shown on his map, were active only during the flood season (Map 7 A).

Comparision of the Carless map, with the ones published around 1900 (Map 7 B) indicates considerable changes in the delta distributaries. A map published with the Gazetteer of the Sind Province in 1907 shows Hujamri and Kedywari as the main distributaries, but the others, Baghar, Mal, and Mutni, had silted up. The 1907 map shows Hujamri and Kedywari very close to one another at a place about 15 miles above the sea coast (Map 7 B). It seems that by this time the Indus River took the main course through Teeteeah, joined Hujamri 15 miles from the coast and abandoned its former course as indicated on the Carless map (Map 7 A). The Teeteeah portion was later named Ochito, and Hujamri was maintained for the southern portion. Sometime between 1907 and the 1920's, the Kedywari branch left its course and joined the sea through the Mutni course. This change is visible in the maps published around 1925. With this change the name of the distributary also changed to Mutni. This
change meant that the distributaries which were very close to one another around 1907 were wide apart.

During 1933-34 the Hujamri course shifted some 12 miles to the west from its former bed. This is indicated by the decay of the port of Vikkur. The Vikkur port was situated a quarter mile from the Hujamri in 1836, according to Heddle (p. 29), but it is now about 12 miles east of the Hujamri. The topographical quadrangles published by the government of Pakistan in 1956 mention this change that occurred in 1933-34.

Comparisons with aerial photographs taken between 1952-54 show further changes which have taken place since 1934. The Ochito is now blocked by a clay plug at its confluence and joins the sea through its eastern branch, and a new small distributary has formed about 6 miles from the sea (Map 7 C).

River Stages

Like weather and climate river stages are subjected to extreme variability from one year to another. In some years the river attains a stage higher than the preceding and furnishes more water to the canals, while in others irrigation suffers from the unexpected drop in the river stage. In the Indus delta the inundation canals receive water only during the river's flood stage. Other systems of irrigation that depend on water from subterranean sources are also affected by river stages. During high river stages the ground-
water table rises close to the surface and shallow wells and other depressions are filled with water and are used for irrigation. Study of river stages, therefore, is of considerable importance to the study of irrigation in the Indus delta.

The Indus River undergoes seasonal high and low stages during the summer and winter seasons. Figure 3\(^1\) shows the gauge readings at the Kotri station, which is about 45 miles north of the delta and was established by the British in 1863 for recording daily levels of the river (Sind, 1912, p.1).

Summer season is the time of high-river stage and water volume increases primarily from melting of glaciers in the watershed area, and from rainfall in the Indus River catchment zone. In the catchment zone of the Indus and its tributaries, namely, the Jhelum, Chenab, Ravi, Sutlej, and Beas (Map 8), an area of over 19,877 square miles remains perpetually under snow (Ahmad, 1958, p.4). In the summer the zone provides an increasing amount of meltwater to the rivers. Rainfall also occurs in the summer from the depressions and storms which are steered northward by clockwise winds on the western periphery of the Far

\(^1\) Gauge readings of ten-year intervals were used to show a generalized pattern of river stages. Figures for the years 1915, 1925, and 1935 were selected from the records published by the Indus River Commission, and figures for 1955 were taken from the files of the government of Pakistan. Data for 1945 were not available.
Fig. 3
Eastern anticyclone that lies over central India at a height 6 km. above sea level (Naqvi, 1959, p. 58). These depressions result in copious amounts of orographic rainfall in the Indus catchment basin. The river starts to rise in April and by June-July it is high enough to flow into the inundation canals. In terms of gauge reading, canals attain their full supply of water when the river rises seventeen feet, which has been called "fair irrigation level" in the Irrigation Reports (Bombay, 1931, p. 1)

Table 6 indicates that the highest stage of the river varies from year to year, but is reached in the latter part of August or early September.

Table 6

<table>
<thead>
<tr>
<th>Year</th>
<th>Date</th>
<th>Maximum Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>1915</td>
<td>August 31</td>
<td>19.6 ft.</td>
</tr>
<tr>
<td>1925</td>
<td>August 14</td>
<td>21.9 ft.</td>
</tr>
<tr>
<td>1935</td>
<td>August 30</td>
<td>23.5 ft.</td>
</tr>
<tr>
<td>1955</td>
<td>September 5</td>
<td>24 ft.</td>
</tr>
</tbody>
</table>

By the first week of October the river drops below the "fair irrigation level" and continues to decrease throughout the winter season, which is the low-stage period. During the low river stage water does not flow into the canals. Irrigation is, therefore, restricted to the summer season. Table 7 shows that the lowest level of the river is also variable, like the highest level, and is
reached sometime during the months of January and March.

Table 7

<table>
<thead>
<tr>
<th>Year</th>
<th>Date</th>
<th>Gauge Reading</th>
</tr>
</thead>
<tbody>
<tr>
<td>1915</td>
<td>February 13</td>
<td>7.4 ft.</td>
</tr>
<tr>
<td>1925</td>
<td>March 30</td>
<td>5.9 ft.</td>
</tr>
<tr>
<td>1935</td>
<td>January 25</td>
<td>0.7 ft.</td>
</tr>
<tr>
<td>1955</td>
<td>February 21</td>
<td>-2.2 ft.</td>
</tr>
</tbody>
</table>

Like the maximum and minimum levels of the river, the period of flow above the "fair irrigation level" also varies from year to year. During the years when the river does not flow above the "fair irrigation level" for a sufficient time, canals are cut off from their water supply sooner and the entire irrigation complex suffers. As an example, in the year 1935 water did not reach the far end of the Baghar and other canals, and consequently agriculture suffered greatly for water (Sind, 1938, p. 26). Table 8 represents the variations in the period of flow above the "fair irrigation level."

Table 8

<table>
<thead>
<tr>
<th>Year</th>
<th>Period of Flow above the Irrigation Level (17 feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1915</td>
<td>67 days</td>
</tr>
<tr>
<td>1925</td>
<td>74 &quot;</td>
</tr>
<tr>
<td>1935</td>
<td>53 &quot;</td>
</tr>
<tr>
<td>1955</td>
<td>40 &quot;</td>
</tr>
</tbody>
</table>
Tables 6, 7, and 8 significantly indicate changes which have taken place since 1915 in three directions: The maximum level of the river has increased; the minimum level of the river has lowered; and the "fair irrigation level" time is reduced to 40 days. These changes are presumably the result of man's continued interference with the river in the way of controlled irrigation. Many barrages have been constructed in the northern area since 1915, which have diverted water into canals before reaching the delta area.

Also north of the delta area during the low stage of the river water is diverted into canals through controlled means which further reduces the river level in the delta. During the high stage enough water is available in the river and the excess amount of water which would have naturally gone into inundation canals is controlled, allowing more water in the river to flow into the deltaic area. Therefore, high levels are attained during the high stage in the delta since 1915, but the period of flow above the "fair irrigation level" has continually decreased with the increasing number of dams and barrages in the northern area diverting water into canals.

Such a view is supported by the changes affected by the construction of Sukkur Barrage. Construction of Sukkur Barrage was started
in 1923 and was completed in 1932 to irrigate 7,406,000 acres.
In 1925 the barrage was under construction and sufficient water was not diverted into the canals which gave 74 days of flow above the "fair irrigation level" in the delta, seven days more than 1915 (Table 8). The Sukkur Barrage was completed in 1932. In the delta it increased the maximum level but reduced the period of flow above "fair irrigation level" to 53 days in 1935, and to 40 days by 1955.

Abnormal changes in the minimum, maximum, and "fair irrigation level" have been recorded during the year 1955, which results from new dams and barrages constructed upstream since the partition of India and Pakistan. Since 1948 the government of India is reported to be utilizing increasing quantities of water from the three eastern tributaries of the Indus, namely, Ravi, Beas, and Sutlej. During the years 1950-1955 new irrigation projects were completed to irrigate 4,304,000 acres in the East Punjab area (Pakistan, 1953, p.11), which consumes a major part of the water. The amount of water formerly contributed by the Ravi, Sutlej, and Beas to the Indus River has diminished, causing these abnormal changes in the river record.

Such changes in the availability of water for irrigation are causing significant changes in the cultural landscape of the
deltaic area. The aerial photographs show many fields which have been recently abandoned for lack of irrigation water.
III. CULTURAL SUCCESSION

The Indus Valley has witnessed many migrations of peoples from the beginning of human history. These peoples, primarily from the west, introduced a series of culture traits which largely constitute the present landscape. Archaeological evidence indicates that the early inhabitants of the Indus Valley were non-agriculturists. Mounds of prehistoric towns and villages which are thought to date from 5,000 to 20,000 years are found in the vicinity of the area (Map 8) (Wheeler, 1955, p. 21). No conclusive evidence has been discovered as to when agriculture began. However, the Indus Valley civilization, a highly developed culture thought to be based upon irrigation agriculture, is known from the excavations at Mohenjo Daro, Harrappa, and other places. This civilization ranges in time from about 3,000 B.C., to 1,500 B.C. During this period agriculture based on irrigation was established and most of the crops common to Southwest Asia today were then grown in the area. Irrigation is assumed because flourishing agriculture was not possible in the Indus Valley without irrigation, which had a semi-arid climate similar to that of the present. It appears that irrigation was introduced into the area from Southwest Asia shortly after the domestication of seed crops. The origin of irrigation will be discussed in a later section.
WEST PAKISTAN
ARCHAEOLOGICAL SITES

- Prehistoric Urban Centers
- Prehistoric Village Sites
- Modern Cities
It is not definitely known as to what type of irrigation, if it was present, was practiced during the Indus Valley civilization. Wells did exist, but their locations indicate that they were not used for irrigation. At Mohenjo Daro, all the wells were located within the city limits (Fig. 4). These wells were apparently used for drinking water and other domestic purposes. No well has thus far been found outside the city limits where, presumably, fields had existed, which leads to the conclusion that wells were not used for irrigation. There is also no evidence to suggest that canal irrigation was practiced in the area during the Indus Valley civilization. Since there is no evidence that wells or canals were used for irrigation in this area, basin irrigation is the only remaining possibility. A similar development of an agricultural civilization based on basin irrigation is found in Egypt. The simpler form of basin irrigation leaves little or no evidence behind as it is a simple technique utilizing the overflow of water from the rivers during flood time. The Indus River rises from snow-melt and rainfall in the watershed during the summer season and causes floods in the lower valley from June through September. At the end of September the river recedes, leaving the adjoining ground wet. Perhaps on these wet grounds early farmers planted crops and harvested them before the next flood season. Based on evidence from other areas it is supposed that
Fig. 4

A well at Mohenjo Daro

Note the different layers of brick indicating different occupation levels which clearly mark additions as the level of the city rose on its rubble.

Photo: Department of Archaeology
government of Pakistan
basin irrigation existed since the beginning of agriculture in the Indus Valley.

Prehistoric Period

That the Indus Valley was populated in pre-agricultural times by a Stone Age people is beyond question. Two ancient sites discovered by Teilhard and Peterson (de Terra, p. 331) in the hills near Rohri conclusively establish this fact. One site is on a limestone hill west-northwest of Sukkur, and the other is located on the Indus bank one and a half miles southeast of Rohri (Map 8). Nothing definite is known about the racial composition of the pre-agriculture people, as no human remains have been found in the excavations.

Risley (quoted by Chatterji, p. 141) believes that the original inhabitants of the Indo-Pakistan subcontinent were Mongoloids. This view was adopted in the official publications of the government of India and Britain, and has had an undisputed recognition until lately. Indian anthropologists, in particular, have now challenged Risley's view; they believe that Negritos were the original inhabitants. The belief that Negritos first inhabited the subcontinent was advanced by Hutton in 1931 (Census of India, Vol. 1, p. 424), based on race-cum-language sequence. The anthropometric studies made by the Anthropological Survey Department of India confirm Hutton's view, which is now widely
accepted (Chatterji, 1951, pp. 142-146).

Very little is known about the culture of these people. Teilhard and Peterson (de Terra, p. 334) discovered flakes and conical cores, which indicate a hunting-gathering way of life. Moreover we may be reasonably sure that these people lived in small scattered groups hunting, fishing, and gathering without knowledge of agriculture.

The earliest evidence of the practice of agriculture in the subcontinent comes from Kile Gul Muhammed site which is located in the foothills adjacent to the Indus Valley. There appears to be a relationship between Kile Gul Muhammed and adjacent sites, with other widespread sites in Baluchistan and the Iranian plateau (Map 8). The distribution of younger sites toward the Indus Valley from the Iranian plateau suggests an eastward movement into the valley. This is concluded from Kile Gul Muhammed, which is estimated to be 6,000 years old (Alcock, p. 41), and Kot Diji, which is about 500 years younger than Kile Gul Muhammed (Khan, 1958, p. 866).

No definite archaeological evidence has been discovered, but Alcock (p. 41) believes that Kile Gul Muhammed folk cultivated wheat and barley, and had domesticated sheep, goats, and cattle. Alcock's contention is based on the similarity of artifacts and houses of Kile Gul Muhammed with the agricultural sites in Iraq,
Syria, and other countries. Khan (1958, p. 866) accepts Kot Diji as a precursor of the Indus Valley civilization, which has an agriculture base. The estimated date of 6,000 years does not mark the beginning of agriculture, because the advanced village life, adobe brick houses, and associated artifacts like the oven indicate that agriculture was well developed in these sites.

Since there have been no significant changes in climate during the last 6 to 7,000 years, as will be discussed later, agriculture could have developed only on the principle of basin irrigation at these places.

Nothing is known about the race of the people, as no human remains have been found. Chatterji (1951, p. 143) believes that Proto-Australoids and Mediterranean races inhabited the subcontinent of India and Pakistan before the arrival of the Aryan speakers. The Mediterraneans may have been the group who introduced irrigation and village life from the Iranian plateau during Neolithic times. By about 5,000 years ago, agriculture with basin irrigation appears to have been well developed, as is represented by the Indus Valley civilization sites, especially those at Mohenjo Daro and Harrappa.

Archaeologists have discovered considerable evidence to show highly developed agriculture in the Indus Valley civilization in the form of storage vessels, granaries, and charred remnants of seeds.
The main crops grown were wheat, barley, sesame, and cotton (Piggot, p.153). Other students, notably Pithawalla, believe that canal irrigation was used to water the fields of these early farmers. Following Fr. Heras, Pithawalla (1937, Pt. II, p.16) says that "an inscription on one of the seals discovered states clearly that two canals were constructed in the month of Kudan (Aquarius), and Mania (Pisces) in the wood-pecker (?) country: another seal records that it took thirteen months to construct a canal," which according to him is sufficient evidence to establish the presence of canal irrigation. Heras and Pithawalla's statements are, however, without foundation, as the inscription on the seals of the Indus Valley civilization have not yet been successfully deciphered (Wheeler, 1955, p.21; Brown, p.29, and others). Aerial surveys have also failed to reveal any trace of ancient canals (Drower, V. I, p.522), which leaves basin irrigation as the only alternative. Traces of embankments and walls discovered around the settlements at Mohenjo Daro suggest that they may have been erected in part to keep out flood water from the settlements and the cultivable area was left open for basin irrigation.

By this time the villages had developed into urban centers such as Mohenjo Daro and Harrappa (Map 8). The time and sequence of events in which the villages developed into urban centers are not known. The process may have been the same as advocated by
Adams (p. 11) for the contemporary civilization of Mesopotamia. The population increased consequent to an agricultural way of life, resulting in the development of larger urban centers. When most of the arable land was occupied, competition for its use probably led to the amalgamation of neighboring villages into urban centers similar to those in the Indus Valley civilization sites.

The culture was next enriched by semi-nomadic Aryans from the west who arrived around 1,500 B.C., and made the Indus Valley their home. After contacts with the people of the Indus Valley they became sedentary agriculturists and continued the former irrigation practices. They developed a complicated religion and introduced the concept of family ownership of the land. The caste system, which now dominates every facet of Hindu life, and the villages surrounded by fences were introduced by the Aryans. These traits still exist at some places in the Indus delta.

Historic Period

At the time of Alexander's invasion of the Indus Valley in 326 B.C., Sind was dominated by the Buddhist religion. This religion was widespread in the valley as is evidenced by the distribution of archaeological sites. Worship stupas and stone-carved figures of Gautama Buddha have been discovered at Mohenjo Daro and other places (Fig. 5). Early in the third century the mighty kingdom of the Buddhist Maurya dynasty developed in India and extended its
Fig. 5
Mohenjo Daro 3000-1500 B.C.

In the background is a view of a second-century A.D., Buddhist supta. This indicates a reoccupation of the site. In the foreground are excavated buildings of burnt bricks.

Photo: Department of Archaeology
government of Pakistan
its territory into Sind. *Arthashastra*, a book written during this time (quoted by Bhargava, p.10), mentions that the kings were much concerned with agriculture and allotted the arable land to peasants for cultivation. Apparently, agriculture was well established but nothing new was added to irrigation. However, any contribution of the Buddhists to agriculture or irrigation is disputed by Masson and his associates (p. 60). According to them, the negative attitude of Buddhist life added nothing new to the landscape. The Mauryans were succeeded by other local Hindu dynasties, which ruled over Sind until the Muslims came in 712 A.D. Hence it may be said that agriculture was continued without any significant change in irrigation practices until the arrival of the Muslims.

Arab Muslims subjugated Sind in 712 A.D., and introduced a new culture into the area. A large number of native people were converted to Islam and since then Sind continues to be a stronghold of Muslims in the Indo-Pakistan subcontinent.

Following the *Holy Quran* (Suratul Baqar, Ruku 36), Muslims gave great importance to agriculture and developed irrigation in many ways. They brought the animal-powered noria, which is locally known as the nar. The nar is a water-lifting device, which raises water from the river, canals, and wells (Fig. 6). Since it is an important technique of irrigation in the Indus delta, it will be discussed in detail in Chapter VI along with other irrigation
Fig. 6

Nar (Noria also called Persian wheel)

The principle involves a small horizontal wheel (a) which is held in place by a permanent vertical axis. The turning of the small horizontal wheel by oxen, camels, or donkeys turns a vertical cog wheel with a long axle (b) which turns the larger vertical water-lift wheel (c).
techniques. Until irrigation dams and perennial canals were introduced, the *nar* was one of the best known methods of lifting water onto the fields for irrigation (Worlidge, p.18).

As agriculture was considered to be a respectable occupation among Muslims, the succeeding dynasties continued the irrigation practices. Among them, the Kalhora dynasty (1720 A.D.) notably concerned itself with the development of irrigation and agriculture. The Kalhora dynasty came into power during the early part of the eighteenth century in the Indus Valley. Many inundation canals (canals dug with levels concordant to river beds) were dug for irrigation under this dynasty, some of which still survive in upper Sind with names like Nurwah, Nasratwah, and others.

Sind was one of the last areas in the subcontinent to come under British control. Though mercantile contacts had been established by the British around 1764, Sind was not conquered until 1843. Significant changes took place in irrigation during the British rule. An irrigation commission was set up in 1899-1900 to improve and maintain the existing irrigation systems. The British undertook improvements broadly along two lines. First, they improved the existing inundation canals, annually dredged the canal beds and provided regulators at places where the canals took off from the river. The water flow could be controlled by these regulators, closing the gates when no more water was needed in the
canals. Second and most significant was the introduction of perennial canals in 1932. Perennial canals assure water throughout the year, and are regulated through a barrage. A barrage is a broad platform of concrete extending across the river. On the platform is erected a heavy masonry bridge with arched openings several yards wide between solid piers. The openings can be closed by iron sluice gates which slide up and down in grooves, and are raised or lowered by a travelling crane to keep the river upstream at the required level to discharge water into the canals.

British rule over the Indo-Pakistan subcontinent ended in August, 1947. British India and the native states were partitioned into two countries, Pakistan and India. In the new organization the Indus delta became a part of West Pakistan. Pakistan is undertaking an over-all improvement of the irrigation systems, and perennial canals are being constructed in the delta for the first time through a barrage located at Kotri. With the cooperation of international agencies, the World Bank, and the United States government, construction of irrigation dams and weirs is the main concern of the agriculture development programs.
IV. ORIGIN AND DEVELOPMENT OF IRRIGATION

Artificial watering of farm land to supply moisture for crops is practiced mainly in arid regions where rainfall is not sufficient to meet crop water requirements. Basically there are three main systems of irrigation. The first is basin irrigation, resulting from the overflow of rivers; the second, the lift system, wherein water is raised from subterranean and surface water sources like rivers and lakes; and, third, in the conduction of water from the surface water bodies like rivers, lakes, and springs through the use of surface or subsurface canals. Irrigation patterns were probably first developed and used in the arid areas from Egypt to West Pakistan. Prehistoric agricultural civilizations in this area utilized the flood plains of rivers and the wetter mountain slopes. The world distribution of these civilizations in regions of water deficiency and the agricultural growth connected with them have led to a variety of views regarding the origin of irrigation.

Origin of Irrigation

Newell and his associate (pp. 1-2) advocate the origin of irrigation in semi-tropical and relatively arid regions, where there is seasonal overflow by large rivers like the Nile. The headwaters of these streams are in the higher plateau or mountain regions where seasonal rain or melting snow produces high river
stages during one of the seasons. In the early stages of agricul-
tural development man learned to guide or assist the overflow
of streams by building crude ditches. Later, canals and other
methods were used to channel water into the fields which were
not watered by natural overflow. As irrigation techniques
developed, irrigation became independent from the natural rise
of the streams. Spinden (p. 270) has gone a step further to say
that agriculture originated from the invention of irrigation in
arid areas. He thinks in arid areas the natural food supply was
lacking as compared to humid areas where enough food was
available for the food-gathering peoples. The paucity of food and
greater demand in arid areas led to the invention of irrigation
and agriculture. Steward (1930, p. 148) and Huntington (p. 444)
follow Newell and Spinden in agreeing that the origin of irrigation
was in arid areas. However, Steward has changed this view
lately (1955, p. 72) and now believes irrigation began with small
dams and ditches as a supplement to rainfall probably in the
upper tributaries of the main rivers. Some have located the
origin of irrigation in Egypt (Ency. Br., V. XII, p. 685).

The notion that irrigation originated in the flood plains in arid
regions, or that agriculture originated from the invention of
irrigation do not appear tenable, for irrigation is the result of and
not a cause of agriculture. Simply, before man can attempt to
irrigate his fields he must have knowledge of agriculture and the characteristics of crops, including their water requirement. This knowledge can be acquired by man only when he has cultivated a particular crop for a sufficient time. Accepting this view, the prehistoric civilizations of the larger river flood plains do not appear to be the places of origin, since irrigation agriculture was well established at these places with the earliest record. The physical conditions as well refute the possibility of origin of irrigation in Egypt or elsewhere in the larger flood plains. In these areas, the original physical landscape was characterized by great floods, shifting river channels, large swamps, marshes, and thickets of reedy vegetation. In order to cultivate and irrigate these flood plains man had first to learn to control the shifting river, drain the swamps and marshes, and clear the vegetation. It is hard to believe that early man did all this and began his experiments with irrigated farming on the largest and most formidable river flood plains (Rostlund, p. 48). The conclusion is, therefore, that these flood plains were settled by a people who already had some experience with irrigation.

The beginning of irrigation implies that man had first acquired the knowledge that artificial watering augments the deficient supply of natural moisture and that deliberate attempts were made through some technique to apply water to the fields. The knowledge
that artificial watering enhances the wild harvest perhaps comes from food-gathering times. In the food-gathering stage, man must have observed that wild grasses grow more luxuriantly near streams and springs and in the dry beds of water courses. The luxuriant growth of wild grasses in proximity to rivers must have resulted from overflow of water from the river banks during the flood season. Such a view is supported from evidence of food-gathering Paiute Indian bands, who lived in the desert and scrub lands of the plateaus and basins of western North America until the late nineteenth century (Forde, V. I, p.173).

According to Forde,

"A Paiute band of a hundred or so exploited a common territory of some hundred square miles. This usually included tracts of a valley floor yielding grass seeds, and wooded ridges providing the most important food sources. Grasses, edible bulbs and roots were most copious where the snow melt provided additional water supply. This suggested a form of irrigation."

Irrigation as a deliberate watering of the fields must have been practiced at the place where agriculture originated. Sauer (p. 74) has suggested the origin of seed agriculture during Neolithic times in Southwest Asia. In the beginning, agriculture probably was practiced without irrigation, as there are regions of copious spring rainfall in Southwest Asia, Syria, the Caucasus, and Palestine, for example. Through the passage of time, early farmers acquired special skills which predisposed them to augment their
harvests by irrigation. The form of irrigation was likely by snow melt or the overflow of rivers, called basin irrigation. Irrigation was probably first practiced in the small river valleys of the foothills of Southwest Asia, an area predominantly arid with sufficiently high mountains to have snow all year round. Snow melts during the summer season and the small streams overflow their banks forming sites for cultivation. Such practices are still common in western foothills of West Pakistan, and support the belief that irrigation originated in the small alluvial valleys in the foothills of Southwest Asia. Irrigation techniques consequently migrated to the more-arid lower river flood plains in Egypt, Mesopotamia, and West Pakistan, which through time became the key irrigation centers.

The practice of irrigation in the Indus Valley civilization is still disputed by archaeologists. Archaeology did provide ample evidence of agriculture, but failed to give any indication of the process of water supply, which led to the common belief that a wet climate prevailed in the area during that time. Evidence, however, imitates against such a view and establishes the belief that the Indus Valley civilization flourished on basin irrigation.

Mackay (1948, p. 77), Marshall (1928, p. 38), Wheeler (1958, p. 9), de Terra (p. 333) and others suggest that 5,000 years ago the climate of the Indus Valley was milder, with abundant rain-
fall. They believe that heavier monsoon rainfall allowed agriculture and caused luxuriant growth of forests. Animals that inhabited the forests are depicted on the seals. The seals depict animals like rhinoceroses, tigers, water buffaloes, elephants, and others (Fig. 7) which are found in well-watered forests. The second line of argument proving heavier rainfall is based on the use of burnt bricks at Mohenjo Daro and Harrappa. The idea implied is that burnt bricks were used to withstand the heavy rainfall prevalent at that time.

The belief that animal figures appearing on the seals and burnt bricks indicate heavy rainfall seems to lack cogency. Many seals display hybrid animals (chimeras), part bull and part elephant, half tiger and half man. Such animals are known never to have existed and thus are not climatic indicators. Perhaps the animals which appear on the seals were the original totems at a pre-agriculture level which must have existed in a hunting territory. The compound animals perhaps symbolize joint clan territory, with a hybrid totem or combined cult (Kosambi, p. 63). Moreover, the belief that animals and burnt bricks prove heavy rainfall is categorically disproved by the recent discovery of an agricultural village site at Kot Diji, estimated to be 5,500 years old and located 25 miles east of Mohenjo Daro. Kot Diji houses are made of sun-dried bricks and stones and there are no animal figures on the
Fig. 7

Seals found at Mohenjo Daro

Note the figures of combined animals on the seals.
seals (Khan, 1958, p. 866). Logically, if the animals and burnt bricks were the result of moister climate as has been advocated by the archeologists, these same features should have appeared at the Kot Diji site.

Similar belief that there has been no significant climatic desiccation during the past 6 to 7,000 years has been advanced by Adams, Zeuner, and Dorf. Adams (p. 7) from studies of charcoal, mollusca, and fauna from the Karim Shahir site shows that rainfall and, even to a greater degree, the floral cover were the same during the Mesopotamian civilization as they are now. Zeuner (p. 28) fixes the last change in the climatic regime as around 7,000 B.C., implying that there has been no significant change since then. Moreover, Dorf (p. 109) from pollen records has concluded that 5,000 to 2,000 B.C. was a period of somewhat higher temperature. This would imply even more arid conditions in the Indus Valley.

Burnt bricks do not appear to be consequent to areas of heavy rainfall, but were developed in the flood plains as a cultural phenomenon. Brick houses as permanent settlements are an expression of settled communities which came into being as a result of the change from a food-gathering to a food-producing economy. Absence of shelters in the food-producing areas led to the building of houses as permanent settlements. The earliest
evidence of the use of sun-dried brick comes from the small village sites. The progressive development of bricks, from sun-dried to burnt, appearing in association with the small village sites and urban centers, indicates that burnt bricks developed consequent to the development of irrigation agriculture.

The above conclusion is attested by archaeological discoveries in the Indus Valley. The sedentary agricultural village sites found at Kile Gul Muhammed and Kot Diji have sun-dried brick houses. At this time irrigation agriculture was in its incipient stage, but by about 3,000 B.C. some of these villages developed into urban sites. By this time, as is represented by the Indus Valley civilization sites, Mohenjo Daro and Harrappa, irrigation agriculture was much developed and burnt bricks were used as construction material. It may have been discovered by this time that sun-dried bricks required only baking in the kiln to fit them for more-exact and permanent function. Similar developmental phases have been observed by Lloyd (V.I, p. 461) at Hassuana and other sites in Mesopotamia, which were using burnt bricks by 3,200-2,800 B.C.

Since the climate has not changed greatly, the conclusion is that the Indus Valley civilization developed on basin irrigation like the Egyptian civilization. Irrigation was well developed in the Indus Valley, and wheat, barley, sesame, and cotton were
grown (Piggot, p. 153). Peoples who already had a knowledge of irrigation and agriculture probably migrated from the western foothills and settled in this area.

Such a conclusion is strengthened by archaeology. The Indus Valley civilization is 1,000 years or more younger than the agricultural sites discovered by Alcock (1955) and de Cadri (1959) in the adjacent foothills in Baluchistan. Alcock discovered an agricultural site at Kile Gul Muhammed, and de Cadri discovered sedentary village sites in small river valleys at Anjira, Tojau, Siah, and elsewhere (Map 8), with subsistence based on cultivation of wheat, barley, and domesticated sheep, goat, and cattle. It appears that later developments in technology shifted the centers of upland valley agriculture to the Indus plain. Nothing definite can be said about the time of shifting of agriculture sites from the foothills to the plains, but possibly it may have been around 3,000 B.C. The cultivation of wheat and barley continued as winter crops, as was the practice in the highland. The river recedes from the floods at the end of summer, leaving the ground wet; wheat and barley could then be sown and harvested as winter crops.

**Development of Irrigation Techniques**

Most irrigation techniques were developed in the flood plains of arid areas. Basin irrigation was developed into canal irrigation
and water-lifting devices developed from simple receptacles to water wheels and other techniques. The bulk of information regarding such developments comes from Mesopotamia.

**Basin irrigation**

Basin irrigation is the oldest form of irrigation, once practiced by the prehistoric agricultural civilizations of Egypt, West Pakistan, and other arid regions where rivers seasonally overflowed their banks. This system became widespread perhaps because it is a simple technique with many advantages. Man simply took advantage of a natural phenomenon and cultivated the flooded areas after the river receded. No further watering was necessary for winter crops of wheat, barley, and flax, which were the main crops grown in prehistoric times. Artificial manuring of the fields was unnecessary because silt rich in decomposed vegetable matter and phosphate was spread over the fields by the natural overflow. No artificial drainage was required because surplus water drained off through the natural drainage system.

From its initial utilization, basin irrigation has developed in many ways for which most of the information is available from Egypt but is lacking in the Indus Valley. Drower (V. I, p. 536) says the overflow in Egypt was retained outside the cultivable areas by a barrier of stones and mud along the banks of the river. Tradition is that Menes (King of Egypt, c. 3,400 B.C.)
was the first to build these barriers to control the Nile (Hurst, p. 39). A small gap was made in the barrier, through which the fields were flooded. When the ground was saturated the hole was closed with mud and the excess water drained off. These improvements probably developed slowly in nearby foothills and mark the first phase of improved basin irrigation. The next step was to construct a dyke around an area not directly contiguous to the Nile banks and then to add more dykes. This gave rise to the Pharaonic system of basin irrigation in which earthen banks were constructed parallel to the Nile and were intersected by cross dykes enclosing a large area (Drower, V. I, p. 536). This system is still practiced in north Egypt to cultivate wheat, barley, and fodder crops (Fisher, p. 462).

In West Pakistan no visual evidence remains to indicate the system of basin irrigation practiced in early times. Perhaps improvements were not made in the Indus Valley along the same lines as they were in Egypt. It does appear, however, that settlements were protected from floods by embankments and walls, and cultivable areas were left open to floods. At Mohenjo Daro, walls and embankments were constructed along the river (Kosambi, p. 50).

Canals

The development and utilization of canals were important
advances on basin irrigation, for they meant that land located at greater distances from the rivers could be utilized for farming. Canal irrigation made agriculture possible in areas where low river stages occurred during the growing season and led to the evolution of surface and subsurface canals. Surface canals were connected to major rivers on concordant slopes. Subsurface canals were excavated in alluvial fans at the bases of mountain slopes and extended to the valleys.

Oldest evidence of canal irrigation comes from the Mesopotamian civilization where canals were used instead of basin irrigation to overcome the unfavorable regimen of the Tigris and Euphrates rivers. The regimen of these rivers is different from that of the Nile and Indus rivers in that the Nile and Indus flood from June through September whereas the Tigris and Euphrates flood from December through May (Fisher, p. 343). The Tigris and Euphrates recede in June and are at their lowest in September and October; therefore, low water occurs at the beginning of the hot season when water is needed most to saturate the ground. Irrigation on a large scale could be possible only through the digging of canals as was practiced in Mesopotamia. It is not known when canal digging actually originated in Mesopotamia, but canals may be as old as the Mesopotamian civilization itself. From the third millenium B.C. onwards there
are many mentions of canal building in the records of the
rulers of Sumer and Akkad and later of the united country called
Babylonia (Drower, V. I, p. 547).

Subsurface canals were developed to protect the water from
evaporation and pollution perhaps at places where little water
was available. According to Forbes (V. II, p. 666) the technique
of subsurface canals was first developed by ancient miners to
draw water from the mines. He believes Armenia is probably the
place of origin of the subsurface canals. The time of origin is not
known.

The subsurface canal is a gently sloping horizontal tunnel that
extends from the alluvial fan or gravel outwash at the foot of
the mountains to the agricultural valley. The rain which falls on
the highlands runs quickly off the bedrock of the mountain face
and seeps into the gravels and sands of the bordering slopes.
About nine-tenths of the runoff water goes underground within
a few miles and is tapped by the subsurface canals. Vertical
shafts to the surface every fifty yards or so are made to dispose
of the excavated debris and to clean the canal periodically (Fig. 8).

The course of the subsurface canal is marked on the surface
by a line of small cones of rubble. Subsurface canals are utilized
primarily in areas where surface water is generally inadequate
and local groundwater is too deep or too saline to be used. The
Fig. 8

Qanat

A simplified longitudinal section of modern subsurface canal (qanat) in Persia. The conduits are often several miles in length with vertical shafts, which may be as much as 300 ft. deep, at intervals of about 50 yards.

Modified from Drower, 1957.
oldest evidence of subsurface canals comes from Mesopotamia, where one was constructed around 1,240 B.C. by an Assyrian monarch (Drower, V. I, p. 534). They were in wide use in Iran in the period of Acamenian kings (6th century B.C. to 321 B.C.) and in West Pakistan about 300 B.C. The Iranians introduced this technique into Egypt and more particularly to the Kharaja oasis probably during the reign of Darius I (521-485 B.C.) (Wilber, p.121). Subsurface canals have also spread to transcaucasia and as far as southern Morocco. Arabs introduced them in Spain about the eighth century A.D., and the Spaniards introduced them into South America (Cressey, p. 44). These subsurface canals are variously known as qanats, karezes, and foggaras. In Iran they are known as qanats, in Baluchistan as karezes, and in Afghanistan as both qanats and karezes (Humlum, p. 318). The word karez is Persian, but is used outside of Iran in Baluchistan and in some parts of Afghanistan. Apparently subsurface canals were introduced to these areas from Iran and their names have not changed. Qanat is an Arabic word meaning a subsurface canal or conduit for water. In the majority of places where subsurface canals are found they are known as qanats, perhaps due to the influence of Arabs. In North Africa they are known as foggaras, with many local appellations (Cressey, p.27). Qanats do not exist in the Indus Valley today but their presence
in Baluchistan, Lasbela basin, and other areas in the immediate proximity suggests that they may have existed in the alluvial fans west of the Indus Valley.

Water-lifting Devices

Various devices have been developed to lift water from lower elevations, as from rivers, canals, lakes, wells, and other water bodies. Changing water requirements have resulted in the development of lifting devices from simple buckets to shadufs (Fig. 13), screws, wheels, and others.

Clay vessels, leather bags, and other receptacles were filled from the surface water bodies and were carried by man to the required places. The amount of water thus raised was sufficient for the small farms and gardens common to early farmers. Such receptacles have been used since early times at many places and in the Indus delta are now the primary container used to raise and carry water for drinking and other domestic purposes (Fig. 9; and Fig. 10).

Well utilization led to the use of leather and clay receptacles tied to a rope which increased the length of the lift. The receptacle is dropped into the well, filled with water, and then pulled vertically to the surface. A plank laid over the mouth of the well enables the drawer to make a more vertical pull from the well. Because the vertical pull is hard labor and
Leather bag used to carry water at Tatta

Note the small leather bags on top which are used to raise water from the wells.

Clay pots used to carry water at Tatta

Note the bucket hanging behind the donkey used to raise water. Animal-pulled carts are used when water is to be carried for long distances.
furnishes only an intermittent flow of water, the use of a pulley for lifting the water was developed. The rope passes over the pulley placed above the well and the receptacle is drawn by a man. Improvements resulted in the invention of a ramp-well based on the same principle. A large leather bag is tied to a rope which passes over a pulley, but instead of a man drawing the receptacles, two bullocks are used (Fig. 11; and Fig. 12) to lift them by going into the ramp pit. This system is used at places where the water-table is low and is also used to lift the water from the marshes in Gujerat (Newhouse, et al, p. 51).

Improvements and modifications of the original concept have resulted in the development of several other types of water-lifting devices. One important type, the shaduf, consists of a pole counter-poised on a fixed support which is designed to allow a vertical sweep. A rope with a receptacle attached is fastened to the longer end of the pole. The operator raises the shorter end, which is fitted with a counterweight, lowering the receptacle into the water. By leaning on the counterweight the filled receptacle is raised and the water is emptied into the pool (Fig. 13) that feeds the ditches running into the fields. The time and place of the original shaduf are not known, but earliest evidence dates to the third millennium B.C., where it appears enscribed on a cylinder seal of the Akkadian period (c. 2400-2200
Fig. 11

A ramp-well

Note the bullocks going into the ramp pit which raises the water through a rope and pulley system, as shown in Fig. 12.

Fig. 12

Water-bag of the ramp-well

Note rope, pulley, and water-filled leather receptacles.
The shaduf uses the principle of a counterweight and sweep to lift water from wells, rivers, and canals.
B.C.) in Mesopotamia. In Egypt it is seen in various forms on ancient Egyptian tomb paintings from about 580 B.C., (Drower, V. I, p. 524). Shadufs are not used in the Indus Valley and there is no evidence that they have ever been used there. Mackay (1932, p. 441), however, has suggested that shadufs may have been used by the Indus Valley civilization to fill the public baths with water, though there is no indication, direct or otherwise, for such a presumption.

Shadufs proved only an intermittent stage in lifting devices, to be succeeded by the development of rotary mechanisms like the Archimedes screw and water wheels which provide a continuous water flow. Rotary devices for lifting water from rivers and canals were developed in Hellenic times. Archimedes of Syracuse (c. 287-212 B.C.) invented the water screw for lifting irrigation water (Gille, V. II, p. 633). Archimedes screws were introduced into Egypt shortly after their invention and were observed in operation in the Nile delta during the first century B.C. by Diodorus. The water screw is still common in certain parts of upper Egypt and other places in the Arab world for small lifts (Fig. 14). The Archimedes screw was introduced into Morocco during Byzantine times and from there spread to western Europe (Forbes, V. II, p. 677). It is not presently used in West Pakistan, nor there is evidence that it had ever been used in
Fig. 14

Archimedes Screw

The Archimedes screw is used to lift water from the canal to an irrigation ditch at a higher elevation.
past.

The next important stage in the history of water lifting was the evolution of the water wheel. The energy of running water was harnessed to move the water wheel and lift the water. Greeks and Romans used this technique, employing rotary motion at places where water had to be raised from great depths, as was the case in mines (Gille, V. II, p. 637). This principle gave rise to the construction of wheels for raising water by utilizing river currents to turn the wheels. The wheels, placed vertically in the water, are turned by the current and attached receptacles fill and empty as the wheel revolves.

Water wheels are often mentioned in classical Latin literature and one of the earliest drawings is on a mosaic from Abamea, Turkey, dating from the second century B.C. (Fig. 15). From this early period they were spread widely by Romans, extending into North Africa and Europe. In Europe these wheels were widely used and probably were the best known method for raising water from rivers. Worlidge in 1675 (pp. 18-19) describes them in some detail:

"The most considerable and universal is the Persian wheel [water wheel], much used in Persia from whence it hath its name, where they say there are two or three hundreded in a river, whereby their grounds are improved extraordinarily. They are also much used in Spain, Italy, and France, and is esteemed the most facile and advantageous way of
Fig. 15

Water wheel
raising water in great quantity to any altitude within
the diameter of the wheel, where there is any current
of water to continue its motion; which a small stream
will do, considering the quantity and height of the
water you intend to raise. This way, if ingeniously
prosecuted, would prove a considerable improvement;
for there is very much land in many places lying
near the river that is of small worth, which if it were
watered by so constant a stream as this wheel will
yield, would bear a burthen of hay, where now it
hardly bear corn."

The next stage of improvement was the invention of the
animal-powered water wheel, noria. The water wheel when
turned by animals could be used at places where currents were
not present, such as in wells or quiet water bodies. There is no
single opinion as to where and when the noria was invented.
Broadly, there are four places of possible origin: Persia, India,
China, and Arabia (Caro-Baroja, 1955, pp.16-17), but the view
most favored is that the animal-powered noria was invented by
the Arabs at the time of Islamic renaissance (Caro-Baroja, 1954,
p. 51). The fact that there is no definite evidence of an animal-
powered noria before the Islamic period favors the view of Arabic
invention. The animal-powered noria is mentioned perhaps for
the first time by an Arabic writer, Ahmad ibn al-Tayyib, in 884-
85 A.D. (Caro-Baroja, 1955, p.22), and is indicated to have been
an important technique of irrigation in the Arab world.

Arab Muslims introduced the animal powered noria to different
parts of the world during their expansion in the seventh and eighth
centuries (Ronna, V.I., p. 558), and it has remained as the major method for water lifting until the present time (Fig. 16).

Nineteenth-century advancement in technology developed techniques like water pumps based on centrifugal and reciprocating principles and tube wells. These water pumps were introduced into the Indus delta after 1951, but their use is presently restricted to supply drinking water (Fig. 17).
Fig. 16

Noria

A noria raising water from the river into a higher irrigation ditch.
Fig. 17

Water pump in the Indus delta

Note the interest of the villagers in the new technique of obtaining water.

Photo: U.S. Department of Agriculture.
Summary of Irrigation Development in the Indus Valley

Basin irrigation was the main form of irrigation in the Indus Valley before the Arabs invaded the area in 712 A.D. In the literature, Maurya and Gupta kings are given credit for developing irrigation in all corners of their empire (Hart, p.19), but apparently nothing new was added to basin-irrigation techniques. The noria with animal traction was introduced into the Indus Valley in the seventh century A.D., and improved the effectiveness of irrigation. With this technique, water from the Indus River, canals, and wells could be lifted from greater depths to maintain a more continuous flow. When the water level is low in river and canals, a cut is made through the bank and the noria is placed in it. When the water table is low in wells, pots are fastened on a loose rope that revolves with the wheel and water is lifted from a maximum depth of twenty-five feet.

Canals were developed very late in both the Indus Valley and the Indo-Pakistan subcontinent. In the subcontinent the first canal of which a satisfactory record exists was dug in 1351 A.D., (Moser, p.146; Smith, V. I, p.306). This canal led from the river Jumna near the town of Delhi, primarily to irrigate the hunting grounds of the Emperor Firouz Tughluk, and secondarily for irrigating cultivable areas (Hart, p.18). Improvements were made on it
during the regime of King Akbar, as appears from a decree quoted by Smith (V. I, p. 307). The decree dates to 1568 A.D., and is as follows:

"The bed (of canal) has become so filled that it is scarcely discernible in consequence of which state of affairs, the Emperor declares that his orders had gone forth during the previous year (A.H. 977 or 1587 A.D.) that the water of the rivers and streams at the foot of hills at Khirzabad, which are collected in the Sombe river, and flow into Jamuna, be brought by a canal deep and wide by the help of dams & c. into the Chetang which is distant from that place about 130 miles, and that canal be excavated deeper and wider than formerly, so that all the water may be available at the above mentioned cities."

Canal digging in the Indus Valley began in the eighteenth century. Canals were dug obliquely along both sides of the Indus River (Chablani, p. 24) to take advantage of the slope of the terrain from the higher natural levees to the lower flanks of the river.

Irrigation was in a decadent state when the British took over the Indus Valley in 1843, but little improvement was made until 1932 when perennial canals and a barrage were constructed. The function of the barrage is to raise the level of the river during dry periods so that the water can be diverted into the canals. It is a broad platform of concrete extending across the river, with its upper surface at approximately bank level. On the platform is
erected a heavy masonry bridge with arched openings several yards wide between solid piers. The openings can be closed by iron sluice gates which slide up and down in grooves, and are raised or lowered by a travelling crane to keep the river water upstream at the required level to discharge into the canals. This system provides complete control of the flow of water in the canals.

Perennial canals were not developed by the British in the deltaic area. British control of the subcontinent ended in the year 1947, and since 1950 attempts have been made by the government of Pakistan to introduce perennial canals in the deltaic area.
V. IRRIGATION PRACTICES IN THE INDUS DELTA

Present irrigation practices in the Indus delta are much the same as those that existed during the early part of the eighth century A.D. Recent developments have tended to reduce the importance of basin irrigation, and increase the importance of canal and well irrigation.

Folk terms classify the prevalent irrigation practices in the Indus delta as moki (مکی), chahi (چهی), and charkhi (چارکی). The term moki is used for basin or canal irrigation, whereas chahi designates well irrigation in which water is lifted by man using a rope and receptacle, and charkhi is used to identify the system of irrigation from wells where a nar (noria) is installed. The terms chahi and charkhi are derived from the Persian words, chah and charkh, meaning a well and a pulley, respectively. The addition of 'i' means either 'from' or 'of' and is appropriately used for water obtained from the wells or with nars. These words appear to have been adopted during the Mughul rule in the Indus Valley after 1500 A.D. Persian was the mother tongue of the Mughuls and was widely adopted during their regime, which explains the widespread use of Persian names.

Basin and Canal (Moki) Irrigation

Basin irrigation was widely practiced in the past in the Indus Valley but its area has become far less extensive since the
construction of continuous artificial levees, known locally as bunds, on both sides of the river (Map 9 C). The levees, which were constructed by the British around 1900 (Sind, 1899-1900, p. 40), are fifteen to twenty feet high. Prior to 1900, artificial levees existed only at some places, perhaps to protect the settlements and other important areas. This practice existed during Indus Valley civilization time and appears to have continued unchanged until British modification. Basin irrigation is now restricted to the area between the two artificial levees (Map 9 C) and is utilized for growing reserved forests of Acacia arabica trees. These forests are owned by the state, and are largely used for providing wood for fuel.

Canal irrigation is widely utilized at present. When the fields are relatively low in elevation and the canals are full, water flows by gravity from the distributary canals onto the fields. When the fields are relatively higher in elevation than the canals, the nar is installed to raise the water into the fields. In the local language, Sindhi, this system of irrigation is known as moki-madad-charkhi. Normally the canals are full by June (Fig. 18) and the water flows naturally into distributary canals (Fig. 19) until August, when the water level begins to drop. When the water level drops one or two feet, a lift is necessary to raise the water to the surface and nars are placed
1900
Modified from Irrigation Report, 1889-1900.
INDUS DELTA MAIN CANALS

1935

1954
Source: Aerial Photos, 1952-54.
Fig. 18

Kalri canal (Map 9)

The level of water indicates that the canal is about full. Note erosion of the banks.
Fig. 19

Distributary canal

Note the irregular pattern of dredging the distributary canal and depletion of its banks. The landowners are responsible for their maintenance, so it is not uniformly dredged.
in cuts through the canal banks (Fig. 20). Normally two *nars*
are installed in the same location to increase the water supply.
In the Indus delta *nars* are the main device for lifting water
and they are operated by animal traction only. The canals
become completely dry by November and irrigation activities
stop (Fig. 21).

The main canals in the deltaic area are abandoned distributary
channels of the Indus River. After each flood season, it is
necessary to dredge the channels to maintain an adequate water
supply for the next year. Before the British period these canals,
known as inundation canals, were maintained by the individual
landowners. The state allowed some remission of taxes for
maintenance work done and this practice still continues in the
case of distributary canals (Lambrick, p. 18). The practice of
clearing and maintaining the canals by individual landowners
is very old and perhaps dates back to the Aryans. Aryans laid
the foundation of family ownership in the Indus Valley and since
there was no centralized authority, canals must have been cleared
and maintained by the villagers. Canal maintenance differed
greatly from one area to another and in time a general deterioration
of canals resulted.

When the British took over the Indus Valley in 1843 A.D.,
canals were in poor condition. A canal department was organized
Fig. 20

Two nars placed on the bank of the canal

Note the dry condition of canals in winter.
Fig. 21

Baghar canal (Map 9) in November

Note the well dug on the bed of the canal to lift water for man and cattle.
to improve and maintain the existing canals in 1844. This department provided regulators to control the water flow, and embankments in the main canals. Masonry regulators were constructed where a distributary canal joined the main canal (Fig. 22). In the south delta, particularly during winter, intrusion of saline ocean water into the canals was a serious problem. During the winter seasons, canals were dry and sea water invaded the canals which caused land deterioration as far as thirty miles inland. To overcome this difficulty, the British introduced regulators with sluice gates at the terminal end of the canals which prevented ocean water from penetrating into them (Fig. 23). In 1900, an irrigation commission\(^1\) was formed to study and make improvements on the existing irrigation system. The map published with the Annual Revenue Report for the year 1899-1900 shows a number of oblique canals dug from the river and its distributaries (Map 9 A). Many canals were small and close to one another, like Nasir, Tigazo, Dangrozo, Rai, and other canals. The close alignment of canals led to considerable difficulty in maintenance. The inefficient system was further weakened by personal differences among landowners (Burton, p. 41). The British closed some canals, as indicated on the map published in 1935 (Map 9 B), whose sources were threatened by changes in the river course. Instead of

\(^1\) India Irrigation Commission, London, 1903.
Fig. 22

Masonry regulator

Note the distributary canal on the left side of the picture.
Fig. 23

Regulator

Regulator at the terminal end of Baghar canal. The iron gates between the pillars are closed in winter.
maintaining these small canals they maintained and improved main canals which were former distributaries of the Indus, like the Kalri, Baghar, and Pinyari. The closing of small canals was necessary after the construction of continuous artificial levees along the river to minimize the problems caused by shifting river channels.

A further change was made in the canals after 1935, consequent to the construction of a barrage and perennial canals at Sukkur to irrigate 7,406,000 acres. Perennial canals utilized most of the water from the river in the growing season and the delta area was deprived of a great deal of its water supply. Landowners and cultivators protested against construction of such canals in the northern area but were assured that the following improvements in the canals of their area would be made (Sind, 1933, p.14 quoted by Pithawalla, 1937, p.43):

"1. Straightening of the old tortuous inundation canals
2. Taking new branches and distributaries
3. Controlling draw-off equalization of distribution of supplies at a higher level."

The present pattern of canals indicates that the British made many changes along the above-mentioned lines after 1935. To eliminate the numerous canal outlets from the Indus, the Pinyari canal became a major water outlet and from it a canal parallel to the Indus was excavated and named the Dhoro Branch (Map 9 C).
The Dhoro branch was cut through the Gungri and Sattah canals (Map 9 C) to provide their water source and to eliminate their direct connection with the Indus. The abandoning of the heads of the Gungri and Sattah canals from the river meant that water could be more effectively controlled from one place and that the hazards of river changes would be reduced. In addition to these changes, the winding courses of the Pinyari and other canals were straightened.

Distributary canals through which water was conducted to the fields were dredged from the main canals. There was no set pattern for digging the distributary canals; they were dug in the direction where water was needed for irrigation but were routed around individual property lines (Map 10).

Secondary distributary canals locally known as karias were dug from distributary canals to conduct water to ditches in the fields (Fig. 24). Digging and maintenance of secondary distributary canals were the responsibility of the landowners. Each secondary distributary canal belonged to a native chief and it was known by his name. The owner did not allow others to use the water from his canal and any attempt to do so caused violence and disorder. This pattern was established during the Talpur regime in the 1750's (Lambrick, p. 18), and has since resulted in the evolution of a distinctive landscape. A number of secondary
INDUS DELTA

DISTRIBUTARY CANALS

- Main Canal
- Distributary Canal

Source: Aerial Photos, 1952-54.
Secondary distributary canal (karia)

A secondary distributary canal joins the main distributary canal with the small field ditches.
distributary canals are dug close to one another so that each man has his own channel (Map 12). Such alignment of secondary distributary canals leads to a tremendous waste of water, as was noted by the British (India, 1901-1903, Pt. IV. Q.133), but it was not changed because of objections from the cultivators who insisted on their right to have separate channels. The length of the channels varied with the distance of the land from the distributary canals.

The secondary distributary canal joins the small field ditches which conduct water onto the fields. The arrangement of the small field ditches forms a checkerboard field pattern. The small field ditches are constructed by building dual levees a few inches apart on the surface of the fields (Fig. 25 A and B). Through this system ninety two per cent of the cultivated area is irrigated, of which ninety per cent is in rice. The area irrigated by the main canals is variable and is subject to river-stage differences. During the early part of this century, irrigated areas varied due to differences in the high stage of the river, but since 1932 the irrigated area is decreasing in the delta because of the introduction of perennial canals and construction of barrages to the north (Fig. 26).

Well Irrigation

Wells have been used as a water source since ancient times.
Fig. 25 A

Small field ditch

The dual-levee small field ditch is joined to a secondary distributary canal.

Fig. 25 B

Secondary distributary canal

The dual-levee small field ditches are joined to the secondary distributary canal on the left.
Fig. 26

CANAL-IRRIGATED AREA

ACRES (Figures in Thousands)

Pinyari Canal

Baghar Canal

Kalri Canal

Sattah Canal
The use of wells implies that early man was aware of the presence of subterranean water and also developed a technique to obtain it. Where wells had their beginning is unknown but they probably originated in the foothills or dry stream beds where loose, unconsolidated materials accumulate and water penetrates deeply. In these locales man probably observed that he could obtain more water by clearing away surface sediments. Later, man enclosed the springs, which made a more permanent water supply available (Clark, p. 6). The practice of enclosing springs appears to be a basic step in well evolution. Digging holes in dry stream beds to obtain water is a widespread practice in arid areas and is also utilized in the Indus delta (Fig. 27).

Well digging and techniques of usage perhaps spread from the foothills or dry stream beds to flood plains with the expansion of settled communities and the adoption of seed agriculture in Southwest Asia. The selection of a likely place for well digging in the plains may have been based on a variety of techniques. One mentioned by Bromhead (p. 145) was to lie face downward before sunrise on the ground with one's chin on the earth at the spot to be tested. If vapor was seen to rise, it was considered an appropriate place to dig a well. This method is recorded by Pliny, repeated by Vitruvius (first century B.C.,) and by
Fig. 27

A simple well

A well dug in the dry bed of the canal to secure water for drinking.
Assidorus in the sixth century A.D. Belidor's *Architecture Hydraulique*, dated 1782, mentions that an empty dry pot was inverted over the ground to see if moisture collected inside it. If the ground within the inverted pot became wet, a well was dug (Bromhead, *ibid.*, p.145). Before 2,000 B.C., in China the divining rod was used to find a suitable place for well digging. Among the Berber tribes of North Africa, the Maf-

aman (literally one who finds water) is a specialist in locating spots for digging wells (Adam, p.37). He is supposed to be gifted and pretends to see light-colored mud below the ground which betrays the presence of water.

The method of digging wells was simple and perhaps similar to that now practiced in Arabia by Bedouins. The Bedouins choose a likely spot in a wadi bed, or near any unexpected patch of vegetation. A hole is then made with the hoe or digging stick (Drower, V.1, p.525) and is deepened until water is obtained. The sides and rims of these holes are protected with brick or stone if they are to be relatively permanent.

Clark (p. 6), however, associates the origin of wells with the development of urban centers in prehistoric times. He believes population growth resulted in an increased density in primary settled areas. With the rise of urban centers and increased population, natural sources of water became inadequate and
additional water sources were necessary. Utilization of subterranean water from wells was a partial solution to the problem. Clark supports his belief with the archaeological discovery of wells in the Indus Valley civilization, the oldest yet discovered, dating back to 3,000 B.C. The form and construction of Indus Valley civilization wells (Fig. 4) do not indicate their origin but rather represent stages of later development. These wells have a circular shaft ranging in diameter from two to seven feet and are lined with specially formed wedge-shaped burned bricks. Evidence of additions to the well shaft is indicated by different kinds of brick which were used to raise the top of the well.

Simple Well (Chahi) Irrigation

Simple well (chahi) irrigation is practiced in some parts of the Indus delta but is not an important system today. Water is lifted by a man using a rope and receptacle to supplement water requirements of small vegetable crops. In the Indus delta the term chahi is used for well irrigation using only manpower, whereas the term charkhi refers to water lifted from wells with the nar.

In the Indus delta where subsurface water is available temporary wells are dug with hoes at locations convenient to the fields. These shallow wells have a diameter of from two and
a half to three and a half feet and no lining of stones or bricks is normally used. To obtain water the farmer stands on one side of the well and drops a receptacle tied to a rope into the well. The receptacle is usually a bucket made of metal and the rope is made from the fibres of a common shrub known as khip (Laptadenia spartium). The farmer draws the water and empties it into a small ditch which runs along the field boundaries into the fields. The small amount of water obtained is used primarily for supplementing water requirements of vegetables.

In comparative terms, well irrigation is secondary to canal and nar-well (charkhi) irrigation in the Indus delta. Potential water supply and soil conditions for well digging are favorable, but the local inhabitants have not taken advantage of it. During the summer flood season the water table rises to within eight feet of the land surface and in the dry season drops to about twenty feet below. The surface is Recent alluvium and wells are easily dug but farmers do not fully utilize well irrigation (India, 1903, Pt. I, p. 41). Records indicate that the British attempted to develop well irrigation in the Indus delta around 1900 A.D. (India, 1903, Pt. IV, Q. 98), but farmers were indifferent to the system and it has never become important. During the year 1920-21 only thirty-six wells for irrigation were recorded (Map 11).

Since 1947 well irrigation has increased in some parts of the
INDUS DELTA

SIMPLE WELLS 1920-21

One dot represents one well

Source: Karachi District Gazetteer, p. 96.
delta. Field work done along the Kalri canal during the years 1955 and 1956 revealed that farmers are being forced to adapt to well irrigation. This results from abnormal population increases in Karachi where water from the Kalri canal is being used for drinking purposes. The shortage of irrigation water is forcing the farmers to use wells for their water source. At the present time the total number of wells in the area is not known but in the Piru Nareja village alone fifteen wells were observed in 1955.

**Nar-well (charkhi) Irrigation**

The term nar-well irrigation is used here to designate the system in which water is lifted from the wells by the use of animal-powered **nar**. Nar-well irrigation is an important practice and appears to have been so since its introduction into the Indus delta. There is no single opinion as to when and by whom the **nar** was introduced into the area. The old Sanskrit literature mentions some kind of wheel, **rahat**, known in the subcontinent around the second century B.C. (Agarvāla, p. 69). This reference, however, does not specify the nature of the wheel; neither does the etymology of the word **rahat** clarifies the issue. **Rahat** is derived from the Sanskrit word **araghat**, meaning a water wheel (Macdonell, p. 26); **araghat** was changed to **arahat** and finally to **rahat**. This same word may have been used for wheels driven by river currents.

Pithawalla (1937, Pt. II, p.16) believes that animal-traction
water wheels were introduced by the Persians, as the name Persian wheel indicates. This belief is unacceptable because the name Persian wheel appears to be a misnomer and probably originated from the accounts of early European travellers. People who saw it first in Persia and then in the Indo-Pakistan subcontinent called it a Persian wheel, while those who saw it first in the subcontinent and then in Persia called it an Indian wheel. The confusion of terms for the nar is supported by the accounts of travellers published by the Hakluyt Society. During his nine years of travel in East India and Persia John Fryer called it an Indian wheel (Fryer, p. 171). His editor, William Crooke, noted that it is more generally known as the Persian wheel. Most of the early European travellers entered the subcontinent of India and Pakistan through Persia and hence it came to be known as the Persian wheel. The term, Persian wheel, is used in the English language only, however. In most areas where this water wheel is found it is known as noria; Spain, Egypt, and the Indus Valley are exceptions. In Spain the wheel is known as noria, azuda, and acena (Caro-Baroja, pp. 55-56); in Egypt as saqiye (Brunhes, p. 347); and in the Indus Valley as nar.

Wheels using animal power were probably introduced into the Indus delta by the Arabs, as indicated by philology and form. In
the Indus delta, the noria is known as nar, which is derived from the original Arabic term noria. The word noria is based on the Arabic noun, Na,ooru, which is itself derived from the verb na’aru, meaning "gushing out of blood from the veins." This word was adopted for the wheels since water continually gushes out of the buckets (Laufer, p. 239).

The present form of nar in the Indus delta conforms to the description of early Arab writers and strengthens the evidence that the animal-traction type was introduced by the Arabs. Awam (V.I, p.129), an Arabic writer of the twelfth century A.D., mentions the construction of the noria. According to him the cog wheel should be well constructed and the axle should be fairly long with the bucket wheel larger and of heavier wood.

The nar of the Indus delta is composed of a small cogged horizontal wheel, interlocked with a vertical cogged wheel which is attached to a large wheel by a log shaft (Fig. 28). Water is lifted with buckets tied onto the larger vertical wheel by a rope net. The small cogged wheel is interlocked with the cogs of the horizontal wheel. A tongue is fastened to the horizontal wheel (Fig. 28) to which a blindfolded bullock is hitched. The bullock, walking in a circle, turns the cog wheel and revolves the water-lifting bucket wheel.

The horizontal wheel (Fig. 29) is made entirely of wood and
Fig. 28

Nar-well

Boys are demonstrating the operation of the nar. Note the irrigated fields in the background.
Fig. 29

Horizontal wheel of a nar

Note the vertical cog wheel interlocked with horizontal wheel on the left side of the photo.
is constructed along established patterns. The diameter of the wheel is about three feet, four inches. Each side is made with twelve slightly curved pieces of carved wood; each piece is one foot, eight inches long. Two sides of the wheel are then joined by vertical wooden posts about one foot, eight inches long. Vertical wooden posts hold the sides of the wheel together and interlock with the cog wheel. Axle ends serve as bearing surfaces which pivot at the top and bottom on anchored beams, and a tongue fastened permanently to the wheel serves to turn it when propelled by an animal.

The vertical cog wheel is made in the same manner and of the same material and dimensions as the horizontal wheel. On one side of the wheel, wooden sticks extend to form cogs which mesh with the vertical wheel. Anchored with spokes through the center of the cog wheel is a ten-foot long, nearly horizontal axle. The other end of the axle forms the center of the bucket wheel and pivots against a beam eight feet long.

The bucket wheel is the largest of the three wheels and has a diameter of about five feet, eight inches (Fig. 30). Each side is made of fourteen curved wooden pieces; each piece is two feet,

\footnote{Measurements appearing in this section are averages of two nars studied in the field during the years 1955 and 1956.}
Fig. 30

Bucket wheel

Note the trough placed near the axle below the buckets.
eight inches long. The sides are separated by fourteen horizontal wooden sticks and are spaced about two feet apart. The horizontal wooden sticks and the sides of the wheel are attached to the central axle by spokes. Two ropes eight to nine inches apart are geared to the wheel. Small sticks are tied horizontally in the ropes every six inches apart. The ropes are made from the fibres of a shrub known locally as khip (Laptadenia spartium). L. spartium, which is native to Africa and Arabia (Jackson, V. II, p. 60), was likely introduced into the Indus delta by the Arabs. The spacing of the sticks on the rope is called a dur (ٍٍٍٍٍٍٍ). In Arabic, dur is used in the sense of a copious and abundant flow (Lane, p. 862) and is used here in the same sense, since the water falls through the openings. The use of khip and the Arabic term connected with the nar further confirms the belief that nar was introduced into the Indus delta by the Arabs. Clay pots or receptacles are tied onto the wheel at intervals of five or six sticks. Rope lengths depend on water tables and the depth of the well; in those studied the rope was thirty yards long with fifteen clay pots attached. As the wheel turns, the vessels fill at the bottom of the well and empty into a trough at the top. The trough is made of wood and conducts the water into a ditch dug on the surface near the well, through which the water runs to the fields for irrigation.
The size of the surface ditch varies according to the amount of water being lifted by the wheel but is usually about nine inches broad and six inches deep. The nar is located close to the fields (thirty to forty feet) to facilitate irrigation. The surface ditch which is about one and a half feet broad and six to eight inches deep carries the water to small ditches within the field. A cut is made through the levees of the small field ditches to divert the water onto the fields for irrigation. This system controls the quantity and flow of water and allows the water to enter the field without force, which is considered advantageous for growing truck-crops.
VI. FIELD PATTERNS

The study of field pattern is a relatively late interest of geographers. One of the early major contributions to field pattern studies was made by August Meitzen, professionally a non-geographer who published a four-volume work in 1895 (Meitzen, 1895). Meitzen was followed by another non-geographer, Gray, who published a book on English field systems in 1915 (Gray, 1915). As the later numerous publications indicate, geographers became interested in such studies only after the 1930s (Bloch, 1931; Aufrere, 1935; and others). These geographers brought out various cultural and physical factors which influence the field pattern. At some places the field pattern evolved as an adjustment to the physical landscape, while at others traditions and habits were responsible for creating a certain type of pattern. As an example, the field pattern in Aran Island (an island off the west coast of Ireland) evolved as a definite adjustment to geologic structure (Klimm, p. 618). On this island the elongate fields are located on terrace-like surfaces between a series of parallel joints in the limestone. In England, the landforms influence the field rotation practices as indicated by the two-and three-field systems of rotation. In the dissected terrain of the English plain where the soils are better,
the two-field system is more common whereas the three-field system is the dominant pattern in the clay vales with poorer soils (Houston, p. 69). In other parts of England, the tradition and habits of the people fashioned fields through enclosure construction such as building fences around individual property. In areas of voluntary enclosure, winding lanes with irregular-shaped fields are common, while in areas affected by the Parliamentary enclosure act, regular fields with broad straight roads with grass on both sides form the pattern (Houston, p. 74).

In the Indus delta cultural factors have been dominant in shaping the field pattern. Factors like irrigation, agricultural implements, trails, roads, and fragmentation of fields account for the complex pattern which exists today. In this context, a field designates an enclosed plot of land used for tillage. Field pattern refers to the shape, size, and areal arrangement of the fields.

Conforming to past influences the present field patterns are generally rectangular or square. Some fields are irregular, ranging from triangular to polygonal shapes. The size of the field is generally small, 4,000 square yards on an average, with a wide range between minimum and maximum sizes of the fields. In Kakarhala village, Tatta District (Map 12), the maximum size of the field is about 13,000 square yards, and the minimum is only
about 1,000 square yards. Most of the fields are bounded on two sides by irrigation ditches, and triangular and polygonal fields are comparatively smaller than rectangular or square fields.

Generally the fields extend along the irrigation ditches and are divided from one another by small dual mud levees, locally known as haddes. In the local language (Sindhi), hadde means the boundary or limit and in the Indus delta it is appropriately used. The dual mud levees are narrowly separated, forming a small channel or ditch which conducts water into the fields. The total mosaic forms a checkerboard pattern. The mud levees also serve as foot paths for going from one field to another.

In addition to the small delineation by mud dikes the large fields are subdivided in the same manner to facilitate flooding for rice cultivation (Fig. 31).

Kakarhala village (Map 12) has 3,752 acres of land in its area, out of which 954 square acres are cultivated. The remainder is either uncultivated land or land where the nucleated village is located. The village is located amidst the fields and was established at the time when the fields were first cultivated. The settlement patterns and their relation to irrigation and field patterns will be discussed later.

The present field patterns reflect three major characteristic features, namely, geometrical shapes, small sizes, and level
Fig. 31

Dual levees in rice field

The mud dikes maintain adequate water level for rice cultivation.
surfaces. These characteristics are the result of irrigation practices, paths and roads, types of agricultural implements, land tenure, and rice cultivation.

Irrigation

The close association between field patterns with irrigation ditches and canals is shown along the primary (main) and secondary distributary canals.

Primary (Main) Distributary Canals

The fields located along the primary distributary canals are small in size, mainly rectangular and square in shape, and appear to be fragments of larger fields. According to prevalent practices, a field owned by a man is equally divided amongst his heirs, which results in as many divisions of one field as there are claimants. The consequent effect of the hereditary system is the evolution of small fields which is the characteristic feature of the present landscape.

The original size of the fields in the area is difficult to establish since early government records are missing. Maps showing the villages and fields, Deh Maps, were made by the British around 1900, in connection with irrigation and settlement surveys, but these maps have subsequently been modified. Therefore the size and pattern of the fields even in the 1900s, is unrecognizable. Presently fields are checked after every five
years or so, and the changes which arise during this interval are recorded on the original maps which obscure the original details (Fig. 32 A and B). This is done to maintain up-to-date government records for tax purposes. A careful study of the field numbers gives a rough indication of relative age and general plan of the division of fields. As fields are progressively divided the new plots are renumbered, and since a consecutive numbering system is used for the entire village, the newly developed plots receive higher numbers. From field studies and comparison of maps it is assumed that the plots bearing low numbers were laid out earlier and adjacent fields with higher numbers were more recently divided. As an example, the fields numbered 751, 591, and 685 (Map 13 D) are located between the fields bearing numbers 59, 66, and 61 (Map 13 D) and represent a more recent subdivision.

From the lower numbers, it seems that the original fields were aligned along the primary distributary canals, and were comparatively larger in size than the present ones. The original fields followed the general direction of the canals like the fields numbered 1, 2, 6, 7, 8, and others (Map 13 A), while the fields located between parallel distributary canals were rectangular or triangular in shape as plots 28, 29, 30, 31, and others (Map 13 B). At some places close alignment of distributary canals created
Original deh title map of Kakarhala village, showing the years when changes were made on the original map.
Note: Years 1933, 1942, and 1953

Fig. 32 A

VILLAGE KAKARHALA
TAPPA (PARISH) KAKARHALA - TALUKA (COUNTY) TATTA

DISTRICT TATTA
Scale 1 inch = 20 Senklyon = 660 Feet.
1 Ghunta = 33 x 33 Feet

YEAR 1933 - 1942 - 1953

Fig. 32 B

Copy of the original deh title map of Kakarhala village.
irregular-shaped fields like field numbered 545, 546 (Map 13 C), and others.

Secondary Distributary Canals

Emergence of new fields consequent to the fragmentation of old fields resulted in the digging of numerous new secondary distributary canals which modified the shape of the original fields. As discussed previously, sharing of water from a common secondary distributary canal is resisted and as new land holdings emerge, more irrigation ditches are dug to irrigate the fields belonging to different landowners.

The secondary distributary canals are small, irregular, and are generally dug at convenient places, essentially within an individual holding. The digging of many small canals resulted in the evolution of numerous small triangular shaped fields such as field 752 (Map 13 D).

Paths and Roads

Before the evolution of roads which took place after the invention of wheeled vehicles, paths were the important avenues of communication. Paths as routes of communication are associated with settled communities, especially after the adoption of agriculture. With an agricultural base, the development of a more complex society resulted in specialization of skills, division of labor, growth of religious centers, the establishment of communities,
and the growth of paths and roads for inter-communication between centers. Judging by the distribution of materials discovered by archaeology, inter-communication and trade began in very early times, and thus the first man-made tracks were formed (Cole, V. I, p. 704). In the Indus delta paths are common and some have been development into roads. The farmers still walk with their families to neighboring villages to trade (Fig. 33).

The establishment and improvement of paths and roads modified the shape and size of adjacent fields. With the introduction of wheeled vehicles paths were widened and they became permanent roads. Roads developed concomitantly with the introduction of wheeled vehicles (Fig. 34). Both the solid and spoke-wheel carts were introduced into the area during ancient times. Solid-wheel vehicles were invented in the Mesopotamian civilization a little before 3,000 B.C., and from there diffused to the Indus Valley (Childe, 1957, V. I, p. 716). In the Indus Valley civilization numerous clay models prove that these carts were used. The under-carriage of the cart is also represented on the seals of the Indus Valley civilization and was constructed in the same manner as are the present village carts. The axle on these carts turns with the wheel (Fig. 35). At the center and bottom side of each side beam two holes are drilled to hold projecting pegs which fit over the axle. The frame consists of two curved
Fig. 33

Dirt road between villages

A farmer and his wife walking from the village where they live to another to trade.
Fig. 34

A dirt cart track

A dirt cart track through fields. Note the fields at the head of the road beneath the acacia trees.
Fig. 35

Solid-wheel cart
beams (Fig. 35) set parallel and joined by two to six cross bars. The cart has a tongue that extends under the cross bars by which it is pulled. Two or three holes are bored on the upper side of the two side beams to hold upright pegs which contain the box. These carts are three and a half to four feet in width and are pulled by two bullocks.

Spoke wheels are first represented by painted clay models in Mesopotamia around 2,000 B.C., and from there diffused to other areas. They are archaeologically recorded in Egypt after 1,600 B.C., Crete 1,500 B.C., and China 1,300 B.C., (Childe, 1957, V. I, p. 212). The spoke-wheel cart (Fig. 36) was introduced into the Indus Valley by the Aryans (Childe, ibid.). Compared to the solid-wheel carts, these carts are better suited to speed and maneuverability. The axle is attached to the under-carriage and does not move with the wheels. The frame consists of a rectangular box which is attached to the axle.

The wheeled carts and the need for roads have influenced the shape, size, and areal arrangement of the fields since their use in the Indus delta. Most roads were established initially between two settlements for communication. Since these roads were utilized by everyone they became common property. As the agricultural pursuits increased in the villages, more available
Fig. 36

Spoke-wheel farm cart commonly used in the Indus delta.
land was brought under cultivation, but the roads were maintained in their original form. The fields were aligned along the roads and were generally rectangular in shape (Map 14).

Some of these roads which existed between the important settlements were widened and hard-surfaced by the British after 1851. Prior to this time no metalled road existed in the area (Aitken, p. 341). The widening of the road further modified the adjacent field patterns (Map 14). The fields became smaller and developed into a narrow elongated strip, a shape which is not common in other parts of the village (Map 14).

**Agricultural Implements**

Ancient agricultural implements are still in use in the Indus delta and the assemblage consists mainly of the hoe, sickle, clod crusher, and the ard plow. All of these implements have had a part in fashioning the field patterns of today. The sickle as a harvesting implement is an expression of small fields, while the hoe, clod crusher, and ard plow have affected the shape of the field patterns. The hoe is used for making ridges and furrows in the fields, while the clod crusher and ard plow have resulted in the evolution of square and rectangular fields.

The hoe is made of an iron blade about fourteen inches long and nine inches broad (Fig. 37). A wooden handle is fitted on one
KAKARHALA VILLAGE
ROADS AND FIELD PATTERNS

MAP 14

Source: Revenue Office, Tatta.
Fig. 37

Hoe and a sickle
end of the blade and the other end is sharpened to facilitate digging. The hoe is used primarily for making cuts in the checkerboard irrigation ditches, for watering the fields, and for making ridges and furrows to plant and irrigate row crops like peppers, carrots, tomatoes, and others (Fig. 38). The ridge-and-furrow pattern displays a definite association with the village settlements. Mostly fields in the immediate vicinity of the villages, where they are easily accessible and properly protected, are put to row-crop culture. The crops are grown in the winter utilizing moisture that remains in the soil from the summer floods. If in some fields more water is needed, it is provided by digging temporary simple wells at convenient places in or near the fields.

The sickle has a curved blade about a foot long with a serrated or sharpened edge and a wooden handle (Fig. 37). It is used for harvesting grain crops which are threshed by trampling of animals on a prepared surface near the village. The sickle, is well-adapted to small fields operated by individual farmers.

The clod crusher, sanhar, is a log of wood about four to five feet long and is pulled by two oxen (Fig. 39). This implement is used to break up clods and to level the fields after plowing, which is especially needed for rice fields. The use of clod crusher with the plow has resulted in level surfaced fields with straight
Fig. 38

A pepper field. Ridge and furrows are made with the hoe.
Fig. 39

Clod crusher (Sanhar)
sides. The oxen that pull the clod crusher or plow are managed more easily in straight-sided fields.

The view that the plow has brought about the evolution of rectangular and square fields is widely accepted (Curwen, 1953, p. 61; Houston, p. 54). Curwen has advanced a simple but convincing argument in support of this idea.

"If you are going to use a plow, you will be making furrows; and so you will mark a straight rectangular area of some size, allowing sufficient length for the furrows so that you do not waste time in turning the plow too frequently. What you may consider the most suitable length for the furrow will depend upon the power drawing the plow: a team of animal will need a furrow of moderate length that will allow fairly frequent pauses only at the end of a furrow and etc..."

Houston discovered with the aid of aerial photos that round fields, which existed during the Neolithic time in southern England before the plow was introduced, changed to square-shaped fields after the introduction of the plow in the Bronze age.

The type used in the Indus delta is the ard or Egyptian plow, har, pulled by two oxen (Fig. 40). The ard plow is well adapted to the Indus delta as it suits the climatic conditions. The ard only scratches a groove in the soil surface, and, therefore, helps to conserve the moisture of the soil (Curwen, 1953, p. 62) in a warm and dry climate.

The ard probably evolved from the digging stick in three
Fig. 40

Ard plow pulled by oxen
distinct stages. According to Bishop (pp. 261-263), the digging stick developed into the foot plow. The next stage of development on the foot plow was the application of human power to pull it. By this method, one individual pushed the implement, one or more others pulled it. This practice attained a wide distribution and existed in nearly every part of the north temperate zone of the old world (Bishop, ibid.). The substitution of oxen for human power marked the third and final step in the evolution of the ard. The association of oxen and the cow with the plow appears to be very old. The oxen were regarded as gods of fertility and it was perhaps the desire to enlist the magical fertilizing force to the soil which led to their association with the plow and other agricultural implements. Such beliefs were more prevalent in areas where wheat and barley were cultivated in antiquity (Bishop, p. 264).

Earliest evidence of the plow is from cylindrical seals in Mesopotamia about 3,500 B.C. (Bishop, p. 266). It is not clear when the plow was introduced into the Indus Valley, but Chatterji (1951, p. 159) believes that the plow was known to the Indus Valley civilization. He based his belief on the vocabulary of the surviving Tamil language which belongs to the Dravidian language group, generally accepted to be the tongue of the peoples of the Indus Valley civilization. According to him the Tamil words 'er' meaning plow and 'Vetaan-mai' meaning 'agriculture' establish the connection.
with the Indus Valley civilization. Kosambi (p. 67) categorically
denies that the plow was known to the Indus Valley civilization.

Chatterji's belief is open to question as nothing has been
discovered by archaeology to indicate the presence of the plow
in the Indus Valley civilization. The plow was possibly introduced
into the Indus Valley by the Aryan speakers around 1,500 B.C.
(Bishop, p. 276; Rostlund, p. 59). After its introduction into the
Indus delta, the plow has survived without fundamental changes
and is still drawn by a pair of oxen as it was in the past.

The plow is simply constructed, consisting of a wooden post
three to four feet long and nine inches wide (Fig. 41). The guiding
lever, muthio, is fastened to the upper end and a sharpened iron
point about nine inches long is fixed in the lower end. The drought
pole, about seven feet long, is inserted into the upright post above
the iron point. The ard has no moldboard but scours the soil to
a shallow depth of five to six inches.

The field pattern in pre-plow time during the Indus Valley
civilization is not known, but on analogy is presumed to be irregular.
The introduction of the ard plow into the Indus Valley after 1,500
B.C. changed the irregular fields to the geometrically shaped
fields which exist today.

**Land Tenure**

In terms of land ownership and inheritance policy, various
Fig. 41

Board and draught pole of ard

Note the method of construction, the guiding muthio, and iron point and tongue.
Land-man relationships have evolved during the last 6,000 years of agricultural development in the Indus Valley. The land-tenure system as practiced in the Indus Valley civilization is not known definitely, but according to Hewitt (pp. 630-638), there was no individual proprietorship in the early times and produce belonged to the community. From the studies of the surviving Dravidian tribes Baden-Powell (p. 160) concludes that no individual proprietorship of land existed in the early days. As populations increased villages began to grow in size and some developed into urban centers; Mohenjo Daro and Harrappa are examples of the larger cities.

The Aryans introduced the concept of dividing the community into family ownership (Hewitt, p. 638) from whence evolved individual ownership. Land held and tilled by a family was family property and could be inherited and sold. Later, when the state assumed control of the land, individual ownership was replaced by the village tenancy system. Under village tenancy, the individual was allowed to keep his former land so long as he paid the required taxes and kept the land under cultivation. If he failed in his state obligation, the land could be taken from him. As long as the individual satisfied the village tenancy requirement, the land could be sold or divided as was done before the village tenancy system was established. This system greatly improved
during the Mauryan time when uncultivated land was given to farmers willing to cultivate it (Bhargava, pp. 9-10). The payment of taxes by the tenants was about one sixth of the harvested crop which was recognized as the king's share. Practically the same conditions prevailed through the Hindu period when a portion of each harvest was paid to the king (Bhargava, p.15).

The Arabs did not introduce drastic changes in the tenure system. Muslim land law differentiated between Muslim and non-Muslim subjects, and levied additional tax on non-Muslims. No Arab was allowed to own any property or engage in cultivation in the conquered lands (Von Kremer, p. 87), and hence land tenure continued to be the same as existed prior to the Arab period.

Few land-tenure changes were made during the greater part of the Mughul rule and the village tenancy pattern continued until the middle of the eighteenth century when land surveys were made on the basis of land types and cultivated areas (Moreland and Ali, p. 20). Four kinds of land holdings were recognized: land under cultivation (polaj); fallow land (parauti); land uncultivated for three or four years (cachar); and land uncultivated for five years or more (banjar). On inferior land that could not support crops each year (parauti, cachar, and banjar) less tax was exacted for ownership. After the land survey new
taxing policies of the Mughuls resulted in the establishment of
the office of tax collector or zamindar. The term zamindar is
adopted from the Persian language and is a compound of two words,
zamin and dar. Zamin means land, and dar is used to indicate
the landholder. The tax collector was remunerated with a per-
centage of the collection or by an allotment of rent-free land.
During the early stage of development the zamindar was an office
rather than an individual with proprietary right to the land. The
office generally developed along hereditary lines, though formal
sanctions of the king were required in every case. This marked
the beginning of zamindar proprietorship and evolution of inheri-
tence laws which still survive. Zamindar proprietorship replaced
the village tenancy system over most of the Indus delta. Village
tenancy remained the tenure system in areas not owned by
zamindars and these dual systems have continued until the present.

When the British arrived in 1843 the Mughul land survey
records were no longer in existence (Aitken, p. 403), but practices
of the dual tenure system were continued, and in addition a Perma-
nent Survey settlement act was adopted in 1862 for tax purposes.
Under this act the zamindars were declared full proprietors of the
areas over which their claims extended. The four existing divisions
of land were recognized by the British but their classification was
changed from the Mughul base to one based upon irrigation facilities.
The classification was flow (moki), lift (charkhi), and flood (sailabi). The land which did not fall under any of the above three categories was classified according to sufficiency and constancy of water flow, and the expenses incurred in supplying water by lift to the fields, as well as the certainty and duration of water.

The British granted large acreages of lands (jagirs) to local chiefs, perhaps to enlist their support. This land was subject to one fourth tax from the net produce. The local chiefs and zamindars were interested in rent and not in land. Some of them lived permanently in cities and only occasionally visited the village to collect rent from the farmers. This practice led to the deterioration of the agricultural output and was stopped through the Bombay Act III (Aitken, p. 415). Under this act every landowner including zamindars and local chiefs was required to build a house in the village in which his land was situated (Map 16). This led to the presence of at least one brick house in each village.

Landowners are completely free to hire or fire farmers at their discretion. Most land is now held under permanent settlement either by feudal lords (outgrowth of local chiefs) or zamindars.

Every landowner possesses a permanent and heritable right of

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1 This classification is strictly for tax purposes and is different from the one presented in this dissertation where moki is used to indicate both flow and flood irrigation.
occupancy to his land. The occupant is entitled to remain in possession of his land from generation to generation, provided he pays the state taxes. If the zamindar does not cultivate a portion of his land for a number of years, it lies fallow and modifies the field pattern from one of continuous cultivation to one where barren and cultivated fields alternate. Inheritable rights of occupancy has resulted in the fragmentation of holdings into small fields which are a characteristic feature of the field pattern. Fragmentation refers to the pattern in which the land is divided between rightful heirs, and through time has resulted in smaller fields and scattered holdings. The land owned by an individual is distributed among his legal heirs so that each will get an equal share from each field. For example, if a father who has three sons and three isolated fields of one acre each dies, the sons will not each take one field, but will receive one third of each field. The result of successive generations from a common ancestor is the division of land into smaller and smaller plots (Indian, 1946, p. 20). Comparison of a 1928 map of Piru Nareja and the present village shows extensive changes in field sizes during the past three decades.

At the present time there are many fields as small as thirty square yards (Field 814, Map 12). The work of the individual farmer becomes more and more difficult and his returns less and less in
small fields. He carries his plow a distance of several miles to
work tiny plots of land and frequently needs permission from his
neighbors to trespass on their land to reach his own.

In January of 1959 changes were enacted by Pakistan to establish
the feudal and zamindari systems (Pakistan, 1959, pp. 1-4). One
landowner is restricted to 500 acres of irrigated land and the
remaining portion of his land is granted to his tenants or other
farmers. The result of this again places ownership in the hands
of individual farmers. The changes are presently under execution
and when completed will result in additional changes of field
patterns.

Rice Cultivation

Level field surfaces and the small mud dikes which enclose
them (Fig. 31) are directly associated with the cultivation of
rice (Schmieder, p. 6). This field pattern is characteristic of
rice culture, which is the most important crop grown in the area.
Ninety per cent of the area cultivated in the Indus delta is planted
with rice. Early maturing varieties of Oryza sativa, locally
known as Sugdasi and Motya are planted because their growing
periods coincide with the flood season of the river.

The area under rice has almost doubled since the British
occupation. The first reliable survey of rice acreage was made
by the British in 1880; when this survey is compared with figures
of 1947\(^1\), an increase of ninety per cent is shown. With the development of rice culture the pattern of level fields and mud dikes became more widespread.

Rice is cultivated differently in the flood plain than in the tidal area of the delta. In the flood plain, seed is broadcast after the fields are plowed. The tidal-area fields are not plowed but are puddled by animals before the seed is broadcast. In the flood plain, a field is plowed two or more times and levelled by a clod crusher (Fig. 39) before the seed is broadcast. This system is locally known as korar sariyun. Plowing begins in April and seed is broadcast either in the later part of the same month or in the early part of May. The river nears high stage at this time and water flows to the fields as soon as it is available in the canals. When the fields do not possess enough moisture to germinate the seeds, they are flooded and the seed is then broadcast on the water (Aitken, p. 227). From the time of germination until harvest the crop requires protection from birds and therefore constant watch is necessary. Bird watching has resulted in the construction of elevated platforms of wooden logs and straw which stand out prominently in every fourth or

\[\begin{array}{ll}
1880 & 124,652 \text{ Acres (Bombay, 1927, p. 95)} \\
1947 & 236,101 \text{ Acres (Data from the files of the Department of Agriculture, government of Sind.)}
\end{array}\]
fifth field (Fig. 42). Bird-watch stands are usually erected in uncultivated areas. A watchman stands on the platform and scares the birds away with a sling and rounded clay balls. Similar clay balls have been discovered at Mohenjo Daro (Mackay, 1932, p. 434) which suggests similar practices during the Indus Valley civilization.

Rice is harvested by hand in October with sharp-edged sickles (Fig. 37). A few inches of rice stubble are left standing and are utilized for grazing livestock. The harvested rice is spread on a threshing floor, khoro, and is trodden by blindfolded bullocks (Fig. 43). Winnowing is done with the use of simple baskets and the wind is utilized to separate the chaff (Fig. 44) from the grain.

In the tidal area rice is grown on the bhal lands. As mentioned previously, bhals are the mudflats formed at the mouth of river distributaries in the tidal area. Mud-levees are erected around the fields in the same manner as those in the flood plain (Watt, p. 601). In December, when the river is at its lowest level, the levees are opened to let sea water flow over the bhal lands. The sea water remains on the land for about nine weeks, from December until February. During the second week of February the levees are closed and the ground surface is puddled by grazing animals (Fig. 45). By the end of February or early March the seed
Fig. 42

Bird-watching platform during the Rice growing season

Note the rice fields in the background. In the foreground is a Bermuda-like grass, botanically known as Cynodon dactylon (Young, p. 46).
Fig. 43

Grain-threshing by blindfolded bullocks

Photo: U.S. Department of Agriculture.
Fig. 44

Winnowing

Winnowing with the use of a basket and utilizing the wind to separate the chaff from the grain.

Photo: U. S. Department of Agriculture.
Fig. 45

Rice field on a tidal mudflat (bhal land) near Keti Bunder (Map 1)

Note mud-levees and buffaloes puddling the field.
is broadcast by men crawling on their stomachs in the water with the basket of seed on their back (Austin, p. 48; Watt, p. 601).

The high stage of the river commences by April and by May or June fresh water spreads over the mudflats.

Aitken (p. 229) mentions a curious method of seed preparation before broadcasting. The seed is first packed in bags and laid in pits filled with sweet water to soak for four days; the bags are then taken out and the seed is spread on a platform of hardened clay for four days during which time the seeds germinate. They are then spread on mats and fresh water is poured over them for a period of two days. At the end of this operation, the seed is ready for sowing.

The crop ripens about the third week of September and is harvested while the field is still under water. The harvester uses a boat or a large mass of straw tied together to form a boat (Balfour, quoted by Austin, p. 48). The rice is carried ashore to high land where it is dried and threshed in a similar manner as the rice of the flood plain.

The rice broadcasting method, with or without plowing the field, is also practiced in remote parts of Southeast Asia and may antedate other methods of planting. It is not known when rice was first introduced into the Indus Valley but archaeologists have found no definite evidence of a rice culture in the Indus Valley.
civilization sites. This may mean that rice did not exist in the area as early as 1,500 B.C., when these sites were abandoned. Childe (1952, p.176) has suggested that rice may have been grown in the Indus Valley civilization and Pusalker (p. 174) has also mentioned that rice was probably grown there.

Southeast Asia is generally accepted as the home of rice (Sauer, p. 27; Grist, p. 3). Rice was known in India in ancient times. Oldt Hindu scriptures and various uses of rice in religious offerings and illnesses bear testimony to the antiquity of it in India. According to Chatterjee (1951, p. 20), rice is mentioned in Athra-Veda about 1,000 B.C. Wheeler (1959, pp. 130 and 142) has reported the discovery of charred grains of rice from Hastinapur in Ganga-Jumadaob (800 B.C.,) and Narda Toli in central India (radiocarbon date of 1336 B.C., ± 125). This is the farthest west and the oldest date where rice has been established on the basis of archaeology. It has not been established that rice was also grown in the Indus Valley during Narda Toli times, but Majumdar (p. 212) claims that rice was exported from the ports of the Indus before the Aryan Sanskrit dialect was known. Philology of the word brinj, used for rice in old Persian, strengthens the belief that rice had diffused as far as Persia before the Aryans. Brinj is derived from biyam of the Telgu language which belongs to the Sanskrit language stock (Chatterjee, 1951, p.21).
Grist (p. 3) has also suggested the diffusion of rice before the Aryans because the names in Zind, Sanskrit, and Persian are alike. Grist, however, does not mention specific names in his statement.

If pre-Aryan diffusion of rice is accepted, the presence of rice in the Indus Valley civilization is likely. Moreover, the primitive system of broadcasting rice and the use of clay balls for scattering birds indicate the antiquity of rice in the Indus Valley.
VII. MODERN SETTLEMENT PATTERN

The modern settlement pattern in the Indus delta is closely associated with irrigation practices and field patterns. Nucleated settlements are generally located along the canals and the fields are in close proximity to them. They vary from large villages to small hamlets; village designates relatively large settlements inhabited by ten or more families and hamlet is used to indicate settlements with less than ten families. Villages are located along main canals, whereas hamlets are usually situated along distributary canals (Map 15). Village and hamlet settlements are primarily residential, and the pattern in which the huts are located in relation to one another indicate a strong family association.

Village

In the Indus delta the nucleated village is the dominant pattern. The huts are clustered close together and no residential buildings are located in the fields surrounding the settlements. Villages are located on the crest of canal banks along abandoned distributaries of the river (Map 15). Whenever abnormally high floods occur in the river, the settlements are partly submerged and inhabitants temporarily migrate to places of refuge. The settlements at relatively lower elevations and farther from the
INDUS DELTA

SETTLEMENT PATTERN

MAP 15

Source: Aerial Photos, 1952-54.
canals are affected more than those located on the higher crests along the abandoned distributaries. The flood water flushes away salt efflorescence from the ground surface and deposits a layer of fine alluvium which fertilizes the fields.

Pithawalla (1939, Pt. II, p. 4) believes that the nucleated settlements were established at places where grass was the natural vegetation and open fields of arable land existed along the banks of canals or the river in the lower Indus Valley. Khan (1957, p. 155) advances similar reasons and says that nucleated villages are the expression of physical control and have evolved at places where water and suitable soil for cultivation were readily available.

Such beliefs are not tenable because nucleated settlements are the result of agriculture in the lower Indus Valley and not the other way about. The adoption of agriculture meant a sedentary way of life and man had to protect his fields from intruders, both man and animal. Plowing and harvesting system also helped establish the nucleated village. Archaeological evidence supports the antiquity of nucleated villages; nucleated villages based on agriculture have been found by archaeologists at Kile Gul Muhammed, Anjira, Kot Diji, and other places. Similar development of nucleated villages consequent to an agricultural way of life has taken place in other areas. Curwen (1938, p. 153)
says that in Denmark nucleated villages evolved with early agriculture. According to Buschmann (p. 19), in south, central, and eastern parts of India clearing of forests for agriculture necessitated a number of hands which resulted in the growth of nucleated villages.

In the Indus delta, every village is surrounded by a pile of cut acacia forming a hedge or fence. Relatively larger and older settlements are surrounded by two or three acacia fences. Surveys done during the year 1955 show three lines of fences around the Piru Nareja village (Map 16) and indicate a close association between these fences and subsequent growth of the village. The innermost fence surrounds the older village section and is made by using a combination of acacia fences and mud-plastered brick walls. The middle hedge protects the brick houses and runs almost parallel to the inner fence. The brick houses belong to the landowners (zamindars) and were constructed around 1900, after the enforcement of Bombay Act III. The third fence is on the outskirts of the village and encircles the mosque and communal property. As the village grew in size another fence was added and in this way an expansion of villages through time can be measured.

Fences are constructed to protect the livestock and other valuables from intruders and thieves and to mark out the settlers.
ment areas from the fields. Security measures are less necessary today, but the practice of erecting fences continues as a culture trait. The concept of fencing villages may have been introduced by the Aryans as a means of defence against unfriendly neighboring tribes.

The contention that tribal nucleated villages were the form of settlement during Aryan times is supported by the etymology of the word deh, which appears with the village names like Deh Piru Nareja and Deh Kakarhala. According to Chatterji (1951, p.156), Aryan invaders introduced two groups of people into the area; one of them was called Dasas or Dasyus, and other Nishades. The Dasa-Dasyu people had extensions in Iran where they were known as Daha people. In modern Persian, dih (meaning country or country side) is derived from Daha, which originally was a tribal name. In the Indus delta, deh, prototype of Persian dih, appears before the names of villages, usually after the name of the founder, and literally means the village of a particular family or tribe. For example, Deh Piru Nareja means village of Pir (religious leader) of Nareja, which is recognized as a distinct group.

Native huts are constructed with an acacia framework covered with reeds and straw, and indicate various local practices. Some huts are completely plastered with mud mixed with
rice straw (Fig. 46); others are plastered on the front portion only (Fig. 47), while others are not plastered (Fig. 48). Field investigations revealed that mud plastering of the huts is roughly associated with the economic and social position of the families. Families which are distinguished for owning the land or having religious leadership plaster their huts (Fig. 46), and this denotes a privileged position in the village community. Other people who have mud-plastered huts are the more prosperous farmers (Fig. 49).

A hut is usually located under trees for shade and is sometimes enclosed by an acacia fence which marks the boundary of the dwelling. The area enclosed by the fence conforms to the courtyard of other houses and is used for a variety of purposes; barn, storage, sleeping, and receptions. Livestock (oxen and cows) are tied to stakes driven in the ground (Fig. 47) to prevent the animals from ruining the house. The result of the area is used to store agricultural implements and the family cart. The area in front of the hut is raised with mud and stones to form a patio (Fig. 48) which is sometimes shaded with acacia limbs and foliage. The patio is used to store fuel, baby cribs, water, and other items of daily use. Often, during the warm weather, the dwellers sleep in the courtyard.

The interior of a hut is a single large room with a flat, thatched roof. Flat roofs appear to be indigenous to the area, as all the
Fig. 46

A mud-plastered hut which belongs to a religious leader.

In the foreground is the acacia fence that surrounds the hamlet. Note the acacia-framed hut covered with reed and straw on the left. The frame construction is on the outside. This is a common type throughout the area.
Fig. 47

A hut with a patio surface plastered with mud and roofed over for shade.

Note the wooden sticks in the foreground, the baby crib, bed (chepoy), and water pitchers near the door.
Fig. 48

A hut with a patio surface made by stone and mud plastering

Note the bullock cart and water pitchers beneath the bed. The earthen jar on the right is used for storing grain. The acacia fence on the right.
Fig. 49

Mud-plastered huts which belong to privileged farmers

Note the acacia logs for fuel and the acacia thicket fence.
houses so far unearthed by archaeology have them. The entire
family shares this one room which also stores grain, valuables,
clothing, and other articles. Rice, the principal food of the
area, is stored in large earthen jars (Fig. 48) shaped similar to
those used in the early Indus Valley civilization. They are usually
placed at the far end of the room or in a protected section of the
courtyard.

The adobe-brick houses belong to the landowners and give
a comparatively prosperous appearance to the village. There may
be one or more brick house in a village, depending on its size,
and the number of large landowners. According to the Bombay
Act III, every landowner is required to build a house in the village
(Aitken, p. 415) to ensure a proper interest in the land. Before the
adoption of this act, landowners usually lived in urban centers
and were interested only in obtaining rent from the farmers. The
size and form of adobe-brick houses vary greatly, depending
on the economic status of the landowner. Generally an adobe
brick house has a living room, suffo, with one or two other rooms
and a courtyard.

Almost all the peoples in the Indus delta are Muslims (Pakistan,
1951, p. 58) and, therefore, the mosque is the most imposing
building in a village. The mosque is well-kept, white washed, and
painted at least once a year before the Id or other festival date
(Fig. 50). It is the most conspicuous feature in the village landscape, with a well and several shops nearby. Every Muslim is required to wash his mouth, hands, and feet in a particular fashion (voozu) before going to prayer, and the well near the mosque is a permanent characteristic feature.

Village elders sit under the shade trees near the mosque and discuss various problems confronting the village. This practice appears to be a survival of the Panchayat system, in which the elders were elected as leaders to run village life, protect properties, and settle disputes. During the British regime this institution lost much of its authority, but it is being revived by the government of Pakistan in a modified form under the Basic Democracies plan.

The population is largely Muslim, and hence graveyards are another conspicuous feature of a settlement. They are generally located far away from the settled areas because village folk are superstitious about spirits, ghosts, and fairies. According to their belief, spirits haunt graveyards, and this idea has led to the location of burial grounds in remote areas.

Hamlets

Small hamlets are often built on artificially raised sites. The huts are constructed of acacia logs and straw to form a semicircle which is enclosed by a thick pile of acacia (Fig. 51). In the hamlet
Fig. 50

Mosque at the village of Piru Nareja

Note the decorations, white-washing and painting of walls.
Fig. 51

A semicircular hamlet enclosed by an acacia fence

Note huts placed end-to-end with no separating walls.
there are no wall divisions between the huts and man, and his animals share the same roof and the same floor. The watch dog is an essential animal and protects the family's possessions from intruders and thieves. All the inhabitants of the hamlet live like one family and share in each others' affairs with little or no privacy.

Pithawalla (1939, Pt. II, p. 5) believes that these settlements are the expression of physical geographic factors. According to him the deltaic area is flat, marshy, and overgrown with mangrove swamp, which makes the clustering of nucleated villages impossible. The argument seems to be unfounded because field studies indicate that hamlets originated consequent to the fragmentation of land holdings. Hamlets are located conveniently to all parts of the fields. Little concern for security prevails in the area and many similar hamlets are developing (Ahmad, 1952, p. 235).

Haig (p. 85) mentions that important settlements existed along the Kalri canal in 1519, when it was an active distributary of the river. These settlements have decayed since the distributary now no longer receives a continuous flow of water. Another change is taking place along the Kalri canal, because the major portion of water from the canal, which was used for irrigation, is now being used for drinking purposes for Karachi. This is adversely affecting the agricultural practices of the settlements
along the canal. The farmers are slowly turning to either
simple well irrigation or acquiring land in other areas where
water is available. Changes in the distributary system of the
river has also resulted in shifts of settlements from one area to
another.
VIII. SUMMARY AND CONCLUSIONS

During this study three aims have been developed: first, a study of the origin, diffusion, and development of different irrigation techniques; second, evolution and relative importance of irrigation patterns in the Indus delta; and third, generic analysis of the present field patterns, with a brief mention of the accompanying cultural landscape.

The origin of irrigation is still uncertain. Its remote antiquity and the wide distribution of its practice have reduced the answer as to where and when irrigation originated to only logical thinking and intelligent guesses. There are two schools of thought as to the origin of irrigation. One is the traditional school, which believes that the water deficit in arid regions led to the practice of irrigation, especially in the flood plains where agricultural civilizations existed about 5,000 years ago. The other considers physical geographic factors of the arid flood plain much too hostile to let early man begin the practice of irrigation. According to this school, irrigation may have originated in the small river valleys, where physical conditions were relatively congenial and manageable by early farmers.

The origin of irrigation involves two stipulations: first, man must be aware of the fact that artificial watering augments the
harvests, and second, he must be familiar with the nature of the crop, including the botanical characteristics and water requirement. The knowledge that artificial watering augments the harvest was probably attained by man during the food-gathering periods when he observed the relatively luxuriant growth of vegetation near streams, springs, and in dry beds of water courses (Forde, V.I, p.173). Familiarity with crops could only be possible after a sufficiently long and close association with agriculture. Irrigation may have originated at a naturally favorable place in Southwest Asia where seed agriculture had its beginning (Sauer, p. 74). Considering the physical setting of Southwest Asia, small river valleys of the foothills appear to be likely places for the origin of irrigation.

It is still open to question as to how the fields were first irrigated. It seems likely, however, that man's first irrigation was simply by streams overflowing their banks. During the summer season perennially available snow on the mountains of Southwest Asia melts, provides more water, and causes an overflow of water from river banks. During summer floods the wet ground in the alluvial valleys was utilized by early farmers to grow wheat, barley, and other crops commonly encountered by archaeologists in the prehistoric civilization sites. From this simple beginning, various techniques of irrigation evolved to fit different natural conditions. Irrigation practices are divided
into three major types: first, basin irrigation, resulting from the overflow of rivers; second, lift system wherein water is raised from subterranean and surface-water sources; and third, conduction of water from surface-water bodies through canals, subsurface canals, and other methods of transporting water.

Basin irrigation is the oldest form and was adopted by the prehistoric agricultural civilizations, especially in Egypt and West Pakistan. Mesopotamian civilization was located in somewhat different natural surroundings and had to develop other techniques to conform to the natural conditions. In Egypt, basin irrigation developed from simple overflow of the river into a checkerboard system of dikes. In West Pakistan, however, no such developments could be determined because of the lack of existing information. Archaeologists who worked in the Indus Valley (Marshall, 1928, p. 38; Mackay, 1948, p. 77; Wheeler, 1958, p. 9) surmised the prevalence of a milder and wetter climate to explain the irrigation-less agricultural base of the Indus Valley civilization.

Water-lifting devices were developed consequent to the changing water requirements through time, accompanying advances in technological level and changes of cultural values. The use of simple receptacle and rope developed into the ramp-well, commonly seen in operation in the Middle East and India. Further improvements and modifications resulted in the development of
several other types of water-lifting devices. Shaduf, based on the principle of vertical sweep, was developed to raise water from surface and subterranean sources. It has not been clearly determined as to where or when shaduf originated, but earliest evidence dates to Mesopotamia during the third millenium B.C. Shaduf proved only an intermittent stage in the lifting devices, and was succeeded by rotary water-lifting devices like the Archimedes screw and the water wheel, which were used before the Christian era.

The canal, an important advance on basin irrigation, was first dug from the major rivers on concordant slopes. The time and place of the origin of canals are uncertain, but the oldest evidence dates back to 3,000 B.C., in the Mesopotamian civilization. Subsurface canals were developed at the places where little water was available, perhaps to counter evaporation and pollution. The subsurface canal is an ingeniously made, gently sloping tunnel which runs from foothill alluvial fans or gravel outwash to adjacent agricultural valleys. According to Forbes (V. II, p. 666), subsurface canals were first developed in Armenia by ancient miners to draw water out of the mines. The oldest archaeological evidence of a subsurface canal dates to 1,240 B.C. in Mesopotamia.

Cultural factors and migrations of peoples are most important
in explaining the irrigation patterns in the Indus Valley. Basin irrigation was practiced during the Indus Valley civilization. Subsequent cultures have since largely adopted the prevailing irrigation technique and made few improvements, perhaps due to its simplicity and many advantages. Basin irrigation partly gave way to canals, a more effective technique of irrigation during and after the regime of the Kalhora dynasty in the eighteenth century. The conclusion that canals were developed so late in the Indus Valley appears surprising, but it is supported by the fact that even now there are relatively few man-made canals. Generally the channels of the abandoned distributaries have been dredged and called canals. The British introduced perennial canals in 1932 largely using the channel beds of former distributaries.

Nar is an important device used for lifting water from the river, canals, and wells in the Indus Valley. Historical records are not available to indicate positively as to when nar was introduced into the area, but on the basis of philology and form it appears that nar was first introduced by the Arabs in 712 A.D.

In the Indus delta, prevailing irrigation practices are much the same as they were during the early part of the eighth century A.D. Irrigation practices are locally divided into three simple types: moki, chahi, and charkhi. Moki, basin or canal irrigation,
has been practiced since early times with varying degrees of development. The continual interference of man with the river has resulted in the decline of **moki irrigation**, notably since 1932. Table 8 and Figure 26 summarize the decrease in irrigation between the years 1900 and 1955 by withdrawal of water in the upper reaches. Artificial levees on both sides of the river, introduced by the British after 1900, have further altered **moki irrigation**, especially basin irrigation. The construction and maintenance of artificial levees has also caused a change in the physical landscape by confining the river to a smaller flood plain within the bounds of the levees.

**Chahi irrigation** designates simple well irrigation, where man draws water with the use of a rope and receptacle. The origin of wells is very ancient and, like the origin of irrigation, implies two prerequisites: First, man must be aware of the presence of subterranean water; and second, he must have developed a technique to obtain it. It is not known definitely as to where wells originated, but physical geographic factors suggest their beginning on the foothills of Southwest Asia. **Chahi irrigation**, which was favored by the high water table and easy accessibility in the area, but they did not succeed due to cultural indifference of the people.

**Charkhi irrigation** uses a **nar** to lift water from the wells. The **nar** has continued to be an important water-lifting device since its
introduction by the Arabs. The importance of nar as an irrigation
device is indicated by its frequent change of name. Nar was
called charkhi by the Persian-speaking Mughuls, and became
widely adopted during their regime around 1500 A.D. It is
called a Persian wheel in English literature, which perhaps
originated from the accounts of early European travellers.

Field patterns are of extreme complexity. The fields are
generally small with geometrical shapes; rectangular and square
ones are frequently separated by irregular-shaped fields. The
continued effect of cultural factors like irrigation, agricultural
implements, trails, roads, fragmentation of land holdings and
rice culture account for this complex pattern. The fields located
along the primary canals are generally rectangular and square
in shape, while the fields located along the secondary canals are
relatively smaller and roughly conform to triangular and
polygonal shapes (Map 13). No historical record is available to
answer the question as to why and precisely when these shapes
evolved. However, in general, the field numbers appearing on the
village maps indicate relative age and hence old field patterns.
Fields associated with the secondary distributary canals are
comparatively younger; they evolved as a result of fragmentation of
land holdings and were modified in shape by the digging of secondary
distributary canals.
Agricultural implements have been mainly responsible for the evolution of square or rectangular patterns. The use of the ard plow modified the former irregular fields to geometrically shaped fields. According to accepted beliefs (Bishop, p. 276; Rostlund, p. 59), the ard plow was introduced into the Indus Valley by the Aryans around 1,500 B.C. The clod crusher, another important implement which is used to level fields, also helped to form square and rectangular ones.

Widening of paths consequent to the introduction of wheeled vehicles modified the shape, size, and areal arrangement of adjacent fields. Both solid-wheel and spoke-wheel carts used in the Indus delta are wide. Solid-wheel carts were invented in the Mesopotamian civilization before 3,000 B.C., and subsequently diffused to the Indus Valley (Childe, 1957, V. I, p. 716). Spoke-wheel carts are first represented by painted clay models in Mesopotamia around 2,000 B.C., and were introduced to the Indus Valley by the Aryans.

Another modifier of field patterns is the system of land tenure which has resulted in small fragmented fields. Every landowner possesses a permanent and heritable right of occupancy of his land and is entitled to remain in possession from generation to generation, subject to fulfilment of certain state obligations. The fragmentation of fields among the legal heirs through time results
in the evolution of markedly smaller fields.

The introduction and importance of rice culture have resulted in level fields. A level surface and mud dikes facilitate flooding of the fields for rice culture and form a mosaic pattern over large areas. The historical records indicate that rice culture increased by ninety per cent between 1880 and 1947. The physical milieu being constant, the technological skill of the British accounts for much of this development.

No archaeological evidence is available to indicate positively the first introduction of rice in the Indus Valley. However, on the basis of philology and other associated inferences, it appears that rice existed as early as the Indus Valley civilization.

In conclusion, the present irrigation systems and field patterns in the Indus delta are the result of a long process of cultural development within and the infusion of traits and ideas from without. Cultural patterns established early were somewhat changed, but present cultural landscape show many ties with the ancient past. Rich in cultural traditions, man in this area has been reluctant to change.

By studying the development and spread of irrigation techniques and settlement patterns, one can discern the present land-man relationships. Basin irrigation is still practiced in the flood plain between the artificial levees. The simple well and nar-well remain
as the main means for tapping the underground water source. The canal has become more important through time and, as canals were built, field patterns were changed. The ancient system of land tenure remains and, as a result, field sizes are small and fragmented. The rise of nucleated villages and hamlets provided man with mutual protection and placed him close to his fields. The development of roads caused additional changes in the field patterns. Modernization is taking place but the patterns of development will neither replace nor radically change the patterns of the past.
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APPENDIX

Glossary of Foreign Terms

Acená, azuda: Spanish names of noria
Banjar: uncultivated land
Bhal: mudflat
Biyam: Telgu word for rice
Brinj: Persian word for rice
Bunds: artificial levees
Cachar: uncultivated land for five years or more
Chahi: simple well irrigation
Charkhi: nar-well irrigation
Deh: village
Dur: space between two sticks on the bucket wheel of nar
Er: Tamil word for plow
Hadde: boundary or limit
Har: plow
Id: Muslim festival
Jagir: large land holding
Karia: small irrigation ditch
Khip: local name for Laptadenia spartium
Khoró: threshing floor
Maf-aman: one who finds water
Moki: basin or canal irrigation

Moki-madad-charkhi: flow-cum-lift irrigation

Motya: a variety of rice

Muthio: guiding lever of ard

Nar: water-lifting device commonly known as noria or Persian wheel

Na'ar: gushing out of blood from veins

Panchayat: council of village elders

Parauti: fallow land

Polaj: land under cultivation

Qanat, karez, and foggaras: subsurface canal

Rahat: a kind of water wheel

Sailabi: flooded

Sanhar: clod crusher

Saqiyyeh: Egyptian name of noria

Shaduf: water-lifting device

Stupa: A Buddhist sacred monumental structure

Sugdasi: a variety of rice

Suffo: living room

Vetan-mai: agriculture

Voozu: washing of face, hands, and feet before prayers by Muslims

Wadi: dry stream bed

Zamindar: landowner
BIOGRAPHY

Mushtaq-ur Rahman was born in Agra, India, on July 1, 1933. He passed the high school examination from the Allahabad Board, Allahabad, India, in 1947. Consequent to partition of the subcontinent, he migrated to West Pakistan with his parents in September 1947. He received his B.A. Honours in 1953, and M.A. in 1955 from Karachi University, Karachi, West Pakistan. In August 1955 he was appointed Assistant Professor in Geography at Islamia College, Karachi. He came to the United States in the fall of 1957 on a Fullbright grant under the sponsorship of the Institute of International Education, and enrolled in the Louisiana State University graduate school where he is presently a candidate for the Doctor of Philosophy degree.
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